REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	09/00/88	

4. TITLE AND SUBTITLE
BASIN A NECK, GROUNDWATER INTERCEPT AND TREATMENT SYSTEM, INTERIM RESPONSE ACTION, ALTERNATIVES ASSESSMENT, FINAL, VERSION 3.2

5. FUNDING NUMBERS

6. AUTHOR(S)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
EBASCO SERVICES, INC.
LAKEWOOD, CO

8. PERFORMING ORGANIZATION REPORT NUMBER
88330R02

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
ROCKY MOUNTAIN ARSENAL (CO.). PMRMA
COMMERCE CITY, CO

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

THIS INTERIM RESPONSE ACTION ADDRESSES A CONTAINMENT, TREATMENT, AND RECHARGE SYSTEM IN THE AREA OF BASIN A NECK FOR CONTAMINANTS THAT ARE MIGRATING FROM BELOW BASIN A. EXTRACTION, TREATMENT, AND RECHARGE ALTERNATIVES ARE REVIEWED BASED ON 1) FEASIBILITY, 2) TIME TO IMPLEMENT, AND 3) COST IN ORDER TO SELECT THE MOST APPROPRIATE TECHNOLOGIES TO MEET THE OBJECTIVES OF THE IRA.

THE ALTERNATIVES ASSESSMENT DISCUSSES THE FOLLOWING:

1. OBJECTIVES AND ASSESSMENT CRITERIA FOR THE IRA
2. HYDROLOGY AND GROUND WATER QUALITY IN THE BASIN A NECK AREA
3. HYDROGEOLOGIC AND TREATMENT ALTERNATIVES FOR INTERCEPTING, TREATING, AND RECHARGING THE CONTAMINATED GROUND WATER
4. COMPARISON OF THE VARIOUS HYDROGEOLOGIC AND TREATMENT ALTERNATIVES
5. PREFERRED TECHNOLOGY
6. ADDITIONAL INFORMATION NEEDED TO REFINE THE CONCEPTUAL DESIGN.

APPENDICES: ALLUVIAL WATER QUALITY SUMMARY, COMMENTS AND RESPONSES.

14. SUBJECT TERMS
HYDROGEOLOGY, WATER QUALITY, CONTAMINANTS, COST, IRA E

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED			

88330R02
2nd COPY

FINAL
BASIN A NECK
GROUNDWATER INTERCEPT AND
TREATMENT SYSTEM
INTERIM RESPONSE ACTION
ALTERNATIVES ASSESSMENT
VERSION 3.2

SEPTEMBER 1988

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

Rocky Mountain Arsenal (RMA) has been the site for manufacture of military chemical agents by the Army since 1942 and of pesticides and herbicides by private industry since 1946. Industrial wastes generated from both Army and lessee activities were routinely discharged into several unlined evaporation basins located on RMA. This practice continued until 1956 when Basin F was constructed with an asphalt liner. Discharge of wastes into evaporation ponds resulted in the infiltration and migration of contaminants into alluvial materials and, in particular, the contamination of portions of the shallow alluvial aquifer (USAEWES, 1985).

To prevent off-post contaminant migration, three groundwater treatment systems have been constructed on the north and northwest boundaries of RMA property. Removal of organics at those treatment systems has been accomplished with granular activated carbon. No inorganic treatment has been performed (COE, 1987b).

Alluvial groundwater below one of the unlined basins, Basin A, flows in part to the northwest through a narrow alluvial valley located between two bedrock highs, Rattlesnake Hill and North Plants Hill. The alluvial valley is known as the Basin A Neck.

One of the Interim Response Actions (IRA) required as part of the proposed Modified Consent Decree is a "Groundwater Intercept and Treatment System in the Basin A Neck Area" (paragraph 9.1 (e), Consent Decree, 1988). This assessment addresses a containment, treatment, and recharge system in the area of Basin A Neck for contaminants that are migrating from below Basin A. The "Remediation of Other Contamination Sources" IRA that is being conducted under the RMA IRA process and "consists of assessment and, as necessary, the selection and implementation of an IRA for the Section 36 Trenches, the Section 36 Lime Pits, the M-1 Settling Basins" and other sites at RMA, is complementary to the Basin A Neck area IRA.

Extraction, treatment, and recharge technologies for the Basin A Neck system have been reviewed for two locations based on technical feasibility, time to

implement, and cost, in order to select the most appropriate alternative to meet the objectives of the IRA. Preliminary cost estimates of the applicable alternative(s) have also been performed.

Sections 2.0 and 3.0 of this assessment review the objectives and assessment criteria for the IRA. Section 4.0 reviews the hydrology and groundwater quality in the Basin A Neck area. Section 5.0 reviews hydrogeologic and treatment alternatives for intercepting, treating, and recharging the contaminated groundwater. Section 6.0 compares the various hydrogeologic and treatment alternatives including preliminary cost estimates. Section 7.0 describes the preferred alternative. Section 8.0 identifies additional information needed to refine the conceptual design. Appendix A contains a summary of raw water quality data. Appendix B contains responses to comments by Colorado Department of Health, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and Shell Oil Company.

2.0 <u>RESPONSE ACTION OBJECTIVES</u>

The purpose of this IRA is to prevent the spread of contaminants now migrating via the groundwater northwest of Basin A. Although this IRA is not the Final Response Action for the contaminated groundwater in the Basin A Neck area, the alternative selected for the IRA will, to the extent practicable, be consistent with and contribute to the effective performance of the Final Response Action. The IRA should be readily expandable and/or modifiable, as necessary, for incorporation into the Final Response Action. This IRA will result in minimization of long-term adverse impacts from the contaminated groundwater in this area.

The specific objectives of the Basin A Neck area IRA are to:

- o Prevent or greatly inhibit the migration of contaminants from the Basin A area through the Basin A Neck alluvial aquifer as soon as practicable; and

- o Collect operational data on the interception, treatment, and recharge of contaminated groundwater from this area that will aid in the selection and design of a Final Response Action.

3.0 ASSESSMENT CRITERIA

The proposed Modified Consent Decree (1988) stipulates that all IRAs shall:

(1) "to the maximum extent practicable, be consistent with and contribute to the efficient performance of Final Response Actions" (paragraph 9.5);

(2) "evaluate appropriate alternatives" and "select the most cost-effective alternative for attaining the objective of the IRA" (paragraph 9.6); and

(3) "to the maximum extent practicable, attain ARARs (applicable or relevant and appropriate requirements)" (paragraph 9.7).

The assessment criteria used to evaluate the various hydrogeological and treatment alternatives are based on these guidelines.

This assessment evaluates and screens "technology processes" as defined by ESE (1988a) to the extent that existing data allow. Although this has reduced the number of alternatives, final selection of the preferred remedial technology process is dependent on acquisition of additional data essential for design. The selected technology process will be subject to review and comment by the Organizations and State as part of the IRA Implementation Document.

Selection of the most effective alternative will be based on the following specific criteria: (1) timeliness; (2) effectiveness; (3) demonstrated performance; (4) availability; and (5) cost. The benefit to the Final Remedial Plan from implementing this response action as an IRA is dependent on an early implementation. Therefore, timeliness of implementation is a primary criteria in the screening and selection of alternatives. Contamination present in groundwater in the Basin A Neck area does not constitute a present threat to the public health or the environment.

ARARs are key criteria in the evaluation of alternatives. The establishment of ARARs for the Basin A Neck IRA, to be completed as part of the total remedial action conducted at RMA under CERCLA 42 USC 9601 ET.SEQ., will identify legal standards for this IRA that are either specifically applicable or relevant and appropriate to the chemicals or procedures of concern. These

ARARs are legal standards to be met to the maximum extent practicable by the IRA. ARARs are discussed in an accompanying document.

3.1 HYDROGEOLOGIC SYSTEM ASSESSMENT CRITERIA

The assessment of the hydrogeologic system alternatives is based on: (1) the aquifer characteristic data as reported by Broughton et al. (1979) and May (1983) and historical drill logs for the Basin A Neck area available at the Rocky Mountain Arsenal Resource Information Center; (2) the feasibility of installing and operating a system under the conditions in the area of Basin A Neck; and (3) the system's ability to mitigate contaminant migration. The system will be operational until implementation of the Final Remedial Plan and will have a lifetime of at least five years.

3.2 TREATMENT SYSTEM ASSESSMENT CRITERIA

The assessment of alternatives for the treatment of groundwater in the area of Basin A Neck is based on: (1) an influent containing organic and inorganic contaminants as established from available data; (2) the feasibility of available technologies for treating contaminants of concern in a timely and cost-effective manner; and (3) effluent concentrations as low as practicable for a given technology. The treatment system will be operational until implementation of the Final Remedial Plan and will have at least a five-year lifetime.

Evaluation and selection of the most efficient treatment alternative(s) are, in part, based on the ability of the alternative to reduce contaminant concentrations and migration. Each alternative is also evaluated for its technical feasibility including proven success in treating the contaminants of interest, reliability, availability, complexity, need for pretreatment, ultimate fate of contaminants or production of hazardous sidestreams, need for pilot studies, and flexibility such that the system could readily be expanded to treat varying influent concentrations or flow rates. Alternatives are also compared based on relative capital and operating costs. Preliminary sizing and costing of the preferred alternative(s) are provided.

4.0 PHYSICAL SETTING

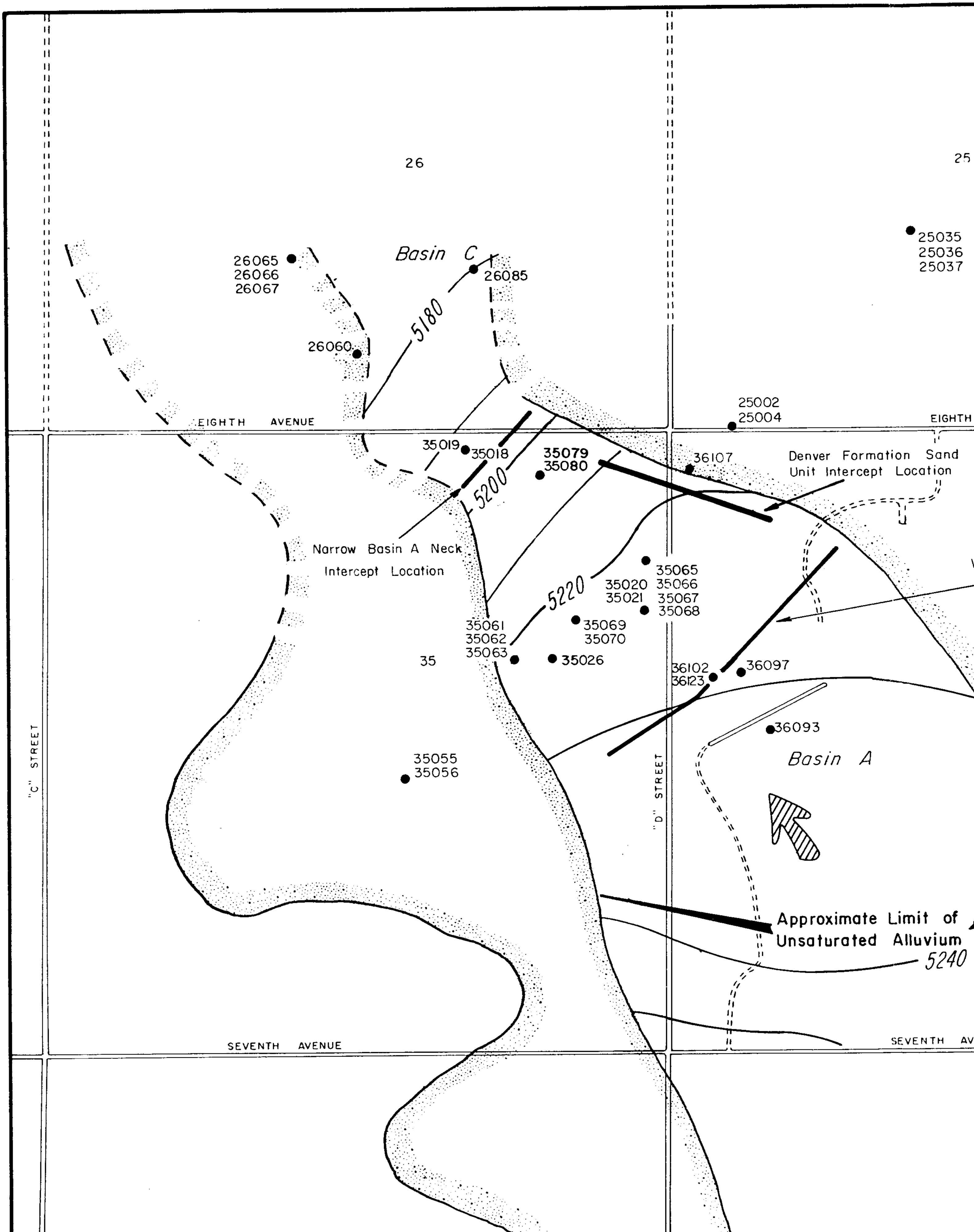
Basin A Neck is a natural pathway for contaminated groundwater flowing out of the Basin A area. This has led to its selection for an Interim Response Action. A description of the physical location, the hydrogeologic characteristics, and the groundwater quality of the Basin A Neck follows.

4.1 LOCATION

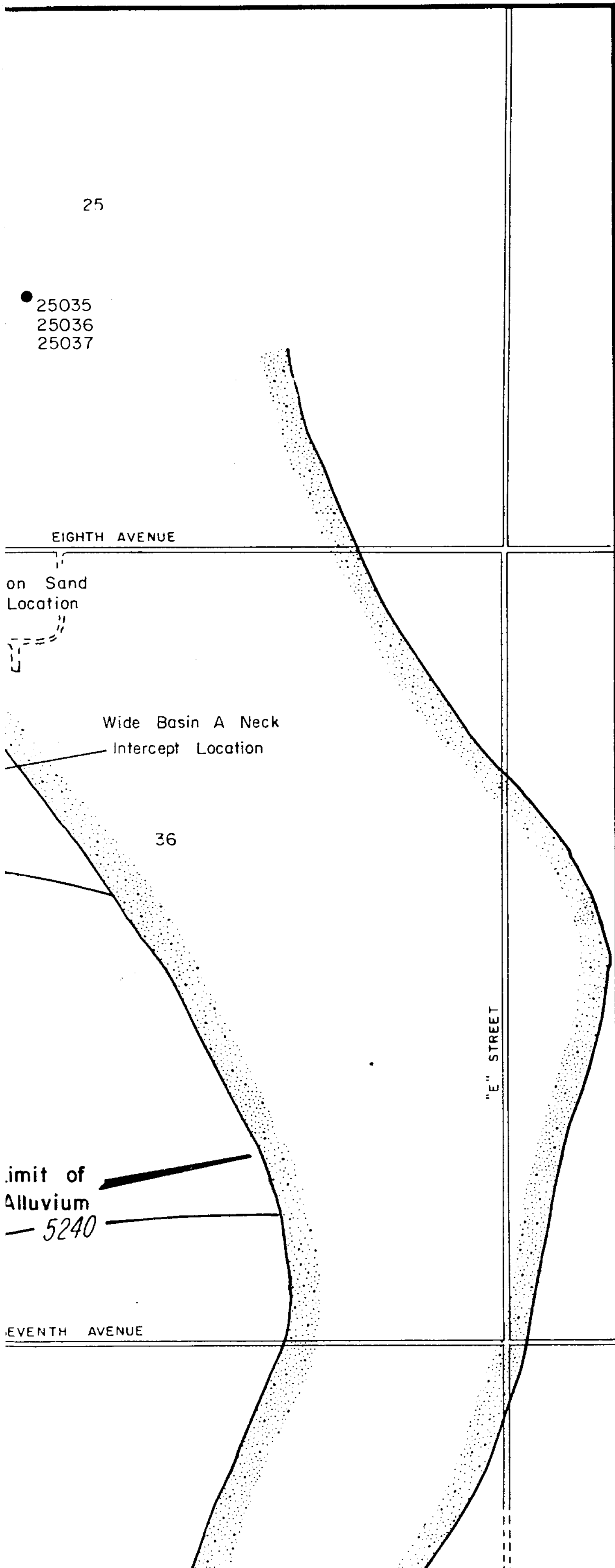
As stated in the proposed Modified Consent Decree (1988), the IRA consists of an alluvial groundwater intercept and treatment system in the Basin A Neck area. The Basin A Neck is a northwest-southeast trending paleo-valley in the surface of the Denver Formation located in the northwestern portion of Section 36, the northeastern quarter of Section 35, and the extreme southern portion of Section 26. The valley has been partially filled with alluvial sediments. Hydrogeologically, the Basin A Neck consists of saturated alluvial material that links the alluvial aquifer below Basin A with the saturated alluvium northwest of the Basin A Neck. The extent of the saturated alluvium in the vicinity of the Basin A Neck is illustrated in Figure 4-1. There is some uncertainty about the configuration of the saturated alluvium downstream from the narrow Basin A Neck in Section 35. A channel has been mapped (ESE, 1988) as turning west towards the Northwest Boundary Containment System and as turning north towards the North Boundary Containment System (ESE, 1986). The narrowest portion of saturated alluvium is approximately 800 feet (ft) wide, but sufficient hydrogeologic data are not available to precisely define the shape of the Basin A Neck. Two sites have been identified as potential locations for a groundwater intercept system. The site in the narrowest portion of the Basin A Neck is termed the narrow Basin A Neck location and the site at the head of the Basin A Neck is termed the wide Basin A Neck location.

4.2 HYDROGEOLOGY

The regional and Basin A area hydrogeologic conditions at the Rocky Mountain Arsenal have been thoroughly discussed in previous reports (May et al., 1983; May, 1982) and therefore are not discussed in detail here. This report will focus on the Basin A Neck area and the specific hydrogeologic characteristics that relate directly to a groundwater control system. Numerous boreholes and



26
25
Basin C
26065
26066
26067
26085
25035
25036
25037
5180
26060
EIGHTH AVENUE
25002
25004
EIGHTH
35019
35018
35079
35080
5200
36107
Denver Formation Sand Unit Intercept Location
Narrow Basin A Neck Intercept Location
35065
35020
35066
35021
35067
35068
5220
35061
35062
35063
35069
35070
35026
35
36102
36123
36097
36093
Basin A
"C" STREET
"D" STREET
35055
35056
Approximate Limit of Unsaturated Alluvium
5240
SEVENTH AVENUE
SEVENTH AV



LEGEND

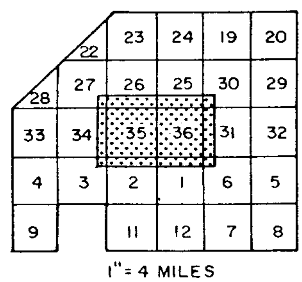
35065 Wells

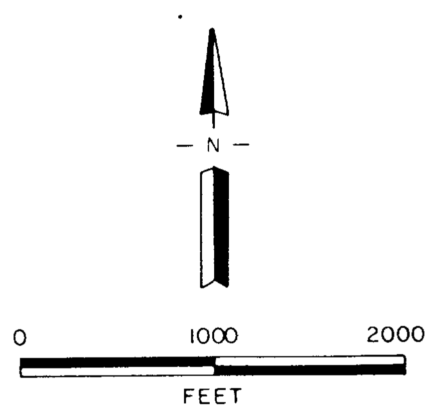
Water Table Elevations

Direction of Groundwater Flow

Sources: ESE, 1986.

ROCKY MOUNTAIN ARSENAL LOCATION





Contour Interval is 10 Feet

Prepared for :

Program Manager's Office for
Rocky Mountain Arsenal Cleanup
Aberdeen Proving Ground, Maryland

5/11/88

Figure 4-1
Generalized Water Table Contours
Basin A Neck Area

Rocky Mountain Arsenal

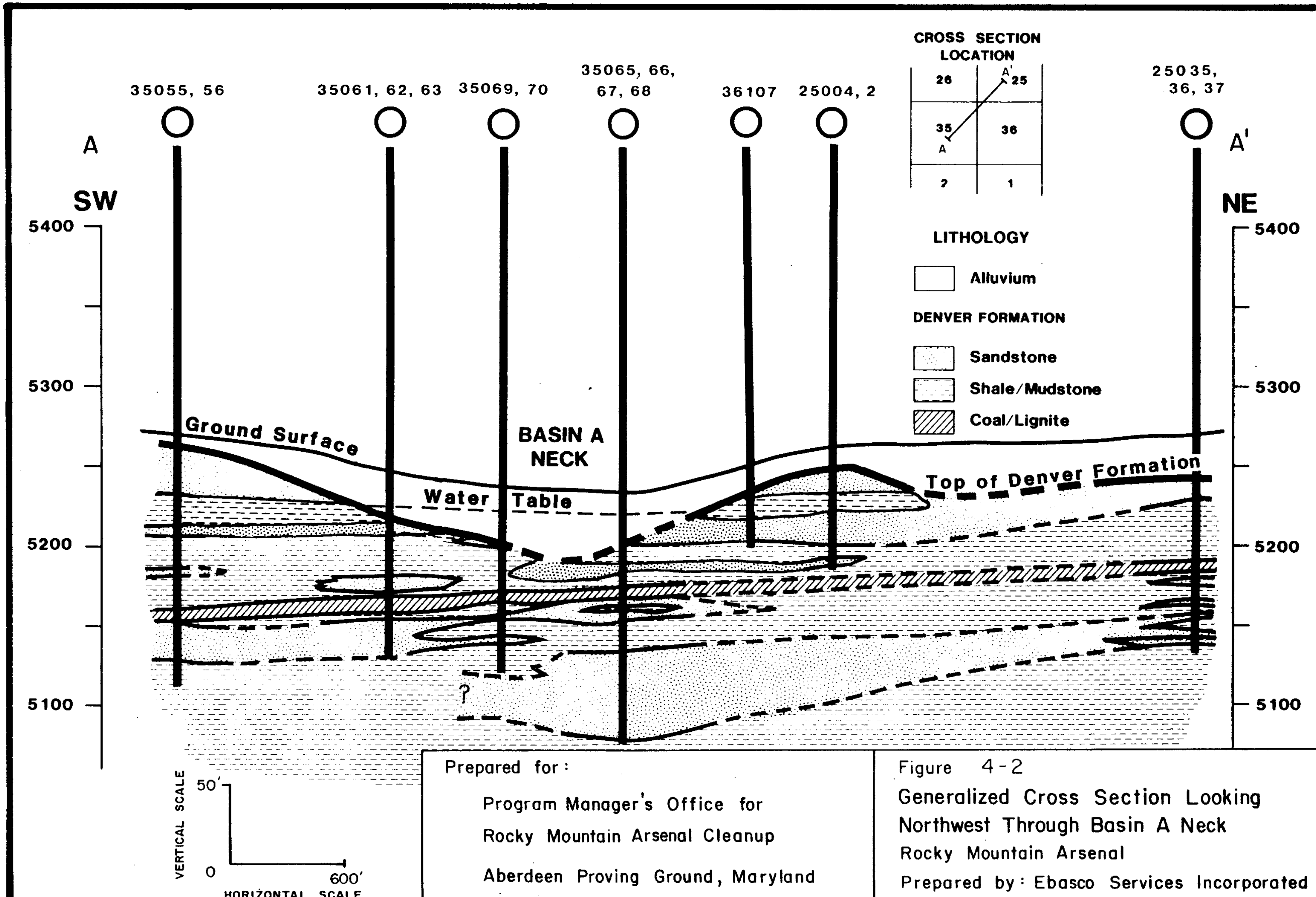
Prepared by : Ebasco Services Incorporated

wells in the area, in addition to the information in previous reports, have been used to characterize the geology and hydrogeology of the alluvial and Denver units in the area of Basin A Neck.

The Basin A Neck is an erosional valley carved in the bedrock surface of the Denver Formation that has been partially filled with alluvial sediments. Denver Formation sediments are exposed on the surface at topographic highs that border the Basin A Neck to the southwest and to the northeast, but bedrock is otherwise blanketed by alluvium. The Denver Formation underlying the alluvium in the Basin A Neck area consists of shale, mudstone, siltstone, sandstone, and lignitic to sub-bituminous coal. Cross-section A-A' (Figure 4-2) illustrates the relative stratigraphic positions of Denver units in the Basin A Neck.

The geology of the surficial deposits in the Basin A Neck area is very complex and is comprised of a variety of soil types and eolian and alluvial sediments. Figure 4-3 illustrates the changes in the alluvial material through this area. The saturated alluvium in the area of Basin A Neck is composed primarily of sand, silt, and clay materials. The silt and clay materials have hydraulic conductivities much lower than the more sandy material. Available data indicate sandy, more permeable materials are more prevalent in the vicinity of the wide Basin A Neck location than in the narrow Basin A Neck. Logs indicate that gravels are locally present in the lower alluvium or upper Denver of the narrow Basin A Neck; however, the full extent of these gravels are unknown.

Alluvium is saturated below Basin A and through the Basin A Neck (Figure 4-1). Large portions of the alluvium overlying bedrock and topographic highs are unsaturated. Saturated thickness of the alluvium varies from 0 ft to more than 30 ft. Alluvial water table elevations indicate that the groundwater flow in this area is toward the northwest. The gradient of the water table steepens from approximately 0.006 feet/feet (ft/ft) beneath Basin A to 0.02 ft/ft through the northwesternmost portion of the Basin A Neck.



Prepared for:

Program Manager's Office for

Rocky Mountain Arsenal Cleanup

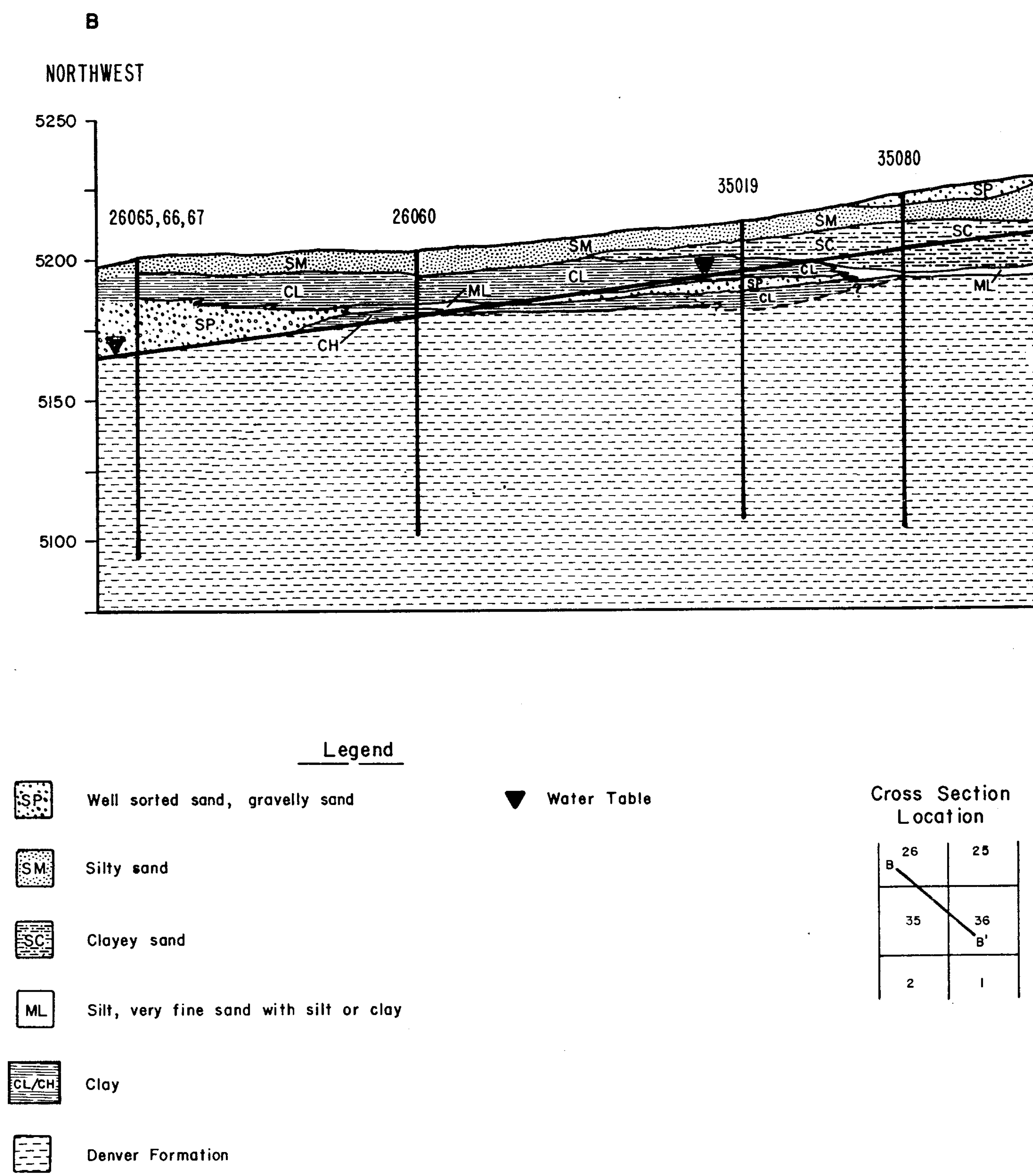
Aberdeen Proving Ground, Maryland

Figure 4-2

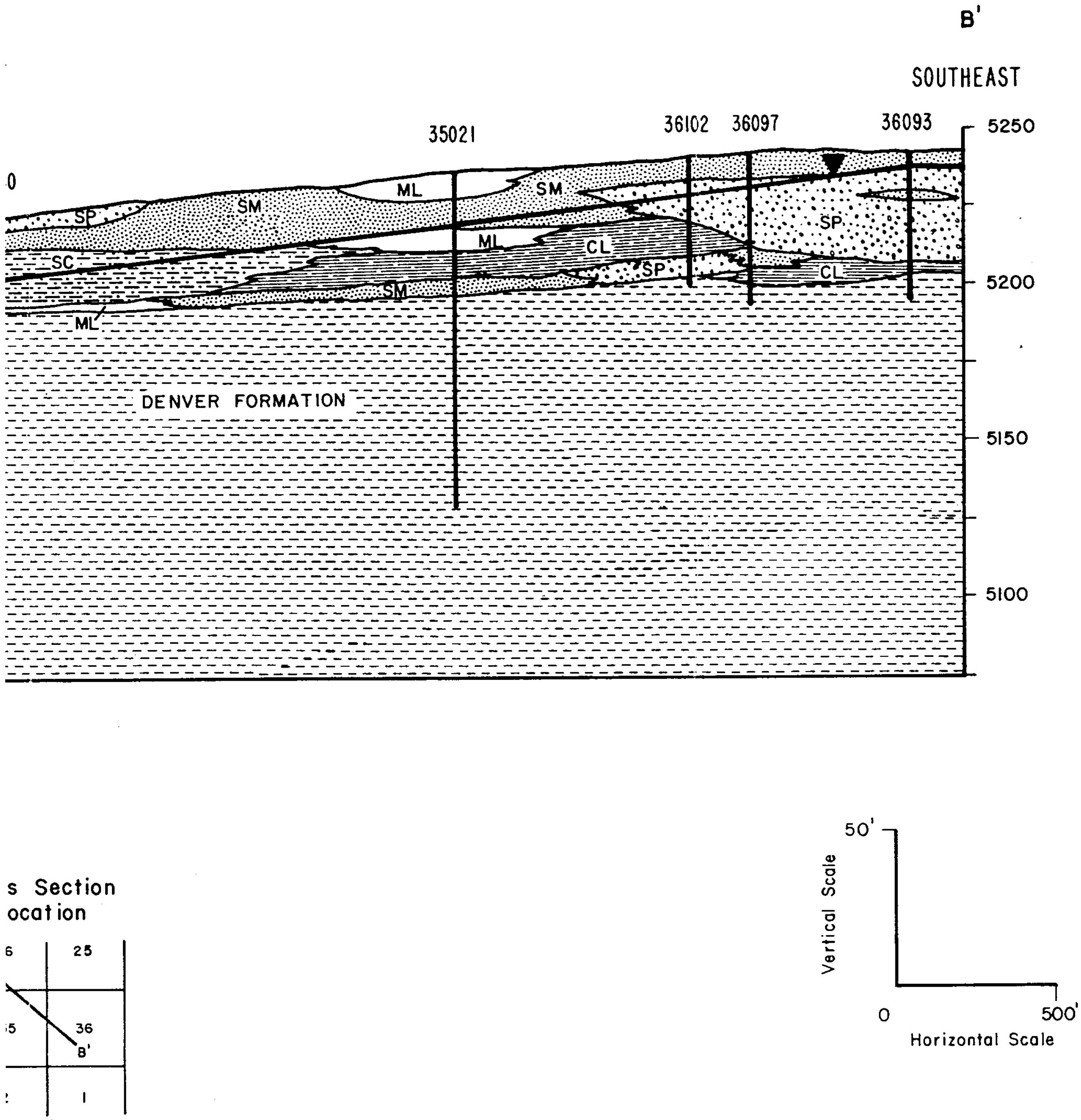
Generalized Cross Section Looking Northwest Through Basin A Neck

Rocky Mountain Arsenal

Prepared by: Ebasco Services Incorporated



B
NORTHWEST
5250
5200
5150
5100
26065,66,67
26060
35019
35080
SM
CL
SP
CH
ML
SC
Legend
SP Well sorted sand, gravelly sand
SM Silty sand
SC Clayey sand
ML Silt, very fine sand with silt or clay
CL/CH Clay
Denver Formation
Water Table
Cross Section Location
26
25
35
36
2
1
B
B'



Prepared for:

Program Manager's Office for
Rocky Mountain Arsenal Cleanup
Aberdeen Proving Ground, Maryland

Figure 4-3

Generalized Cross Section Looking Northeast Through Basin A Neck

Rocky Mountain Arsenal

Prepared by: Ebasco Services Incorporated

Hydraulic conductivities of the alluvial sediments within the Basin A Neck have not been fully characterized. Table 4.2-1 presents the results of falling head permeability tests that have been conducted in three wells in or near the narrow Basin A Neck. The average estimated hydraulic conductivity from these three wells is 1.05 feet per day (ft/d) or 3.7 x 10^{-4} centimeters per second (cm/sec). Comparison of lithologic descriptions of sediments penetrated by borings in the Basin A Neck area indicates the materials in these three wells may be representative of much or most of the alluvial aquifer within the narrow Basin A Neck.

As stated previously, some logs indicate the limited presence of more permeable alluvial materials such as sand and gravel in the narrowest portion of the narrow Basin A Neck. Much or most of the alluvial groundwater flow through the narrow Basin A Neck may be through these more permeable materials even though the material is limited in areal extent. Coarser units may also provide the best dewatering and/or recharge zones; however, the hydrogeologic characteristics and the full extent of the sand and gravel zones within the Basin A Neck have not been determined. The coarser grained units described on well and boring logs and the higher hydraulic values from field tests have been identified primarily at the north end of Basin A, although they may be present elsewhere. A pumping test in Well 36123 in Section 36 near Basin A yielded an average hydraulic conductivity estimate of about 8.8 ft/d or 3.1 x 10^{-3} cm/sec (May, 1982) and may be more representative of the coarser sediments in the Basin A Neck.

The volume of groundwater flowing through the wide Basin A Neck is estimated using Darcy's Law. With a hydraulic conductivity of 3.1 x 10^{-3} cm/sec, an estimated hydraulic gradient of 0.006 ft/ft, and a saturated cross-sectional area of 51,500 square feet (sandy units below the water table), the flow through the wide Basin A Neck is estimated to be approximately 14 gpm. Previously, the flow had been estimated at 34 gpm (May et al., 1983).

Table 4.2-1

Aquifer Test Results in the Vicinity of the Basin A Neck

Well	Type of Test	Estimated Hydraulic Conductivity	Predominant Aquifer Descriptions
35018	Falling Head*	1.16×10^{-4} cm/sec	Silty clay with sand
35020	Falling Head*	2.08×10^{-4} cm/sec	Sand, silty sandy clay
35026	Falling Head*	7.78×10^{-4} cm/sec	Sandy clay
36123	Pumping Test**	2.4×10^{-3} to 6.9×10^{-3} cm/sec	Fine silty sand, sand, clay

*Source: Broughton et al., 1979

**Source: May, 1982

The flow has also been estimated for the narrow Basin A Neck using the same hydraulic conductivity found in the more permeable units of the wide Basin A Neck, 3.1 x 10^{-3} cm/sec, and an estimated hydraulic gradient of 0.02 ft/ft. If it is assumed that flow is primarily through the more permeable saturated sand and gravel units, then the cross-sectional area would comprise 3,200 square feet and the flow rate would be approximately 4 gpm, including approximately 1 gpm flowing through adjacent clayey units. If the same hydraulic conductivity is assumed for the entire cross-sectional area of saturated alluvium (13,000 square feet), the flow rate would be 11 gpm. However, this hydraulic conductivity is an order of magnitude greater than current data indicate.

As mentioned previously, underlying gravel units in the narrow Basin A Neck may serve as alternate flow paths. If the gravel units are extensive, the flow rates could be substantially different from those indicated above.

Information from water balance calculations and from the previously described uncertainties in estimated flow through the Basin A Neck indicate that groundwater discharging from the Basin A area may be flowing through pathways other than through the narrow Basin A Neck. One of these areas may be the permeable Denver Formation sand units that crop out adjacent to the Basin A Neck on the slopes of the bordering bedrock highs. The potential for lateral flow from the alluvium into a Denver sand unit is apparent in Figure 4-2. For Denver sand units that underlie the Basin A Neck area, the flow may be reversed as water levels from these units indicate the groundwater is discharging from the underlying Denver sand units into the alluvium in the Basin A Neck and adjacent Basin A areas.

4.3 WATER QUALITY

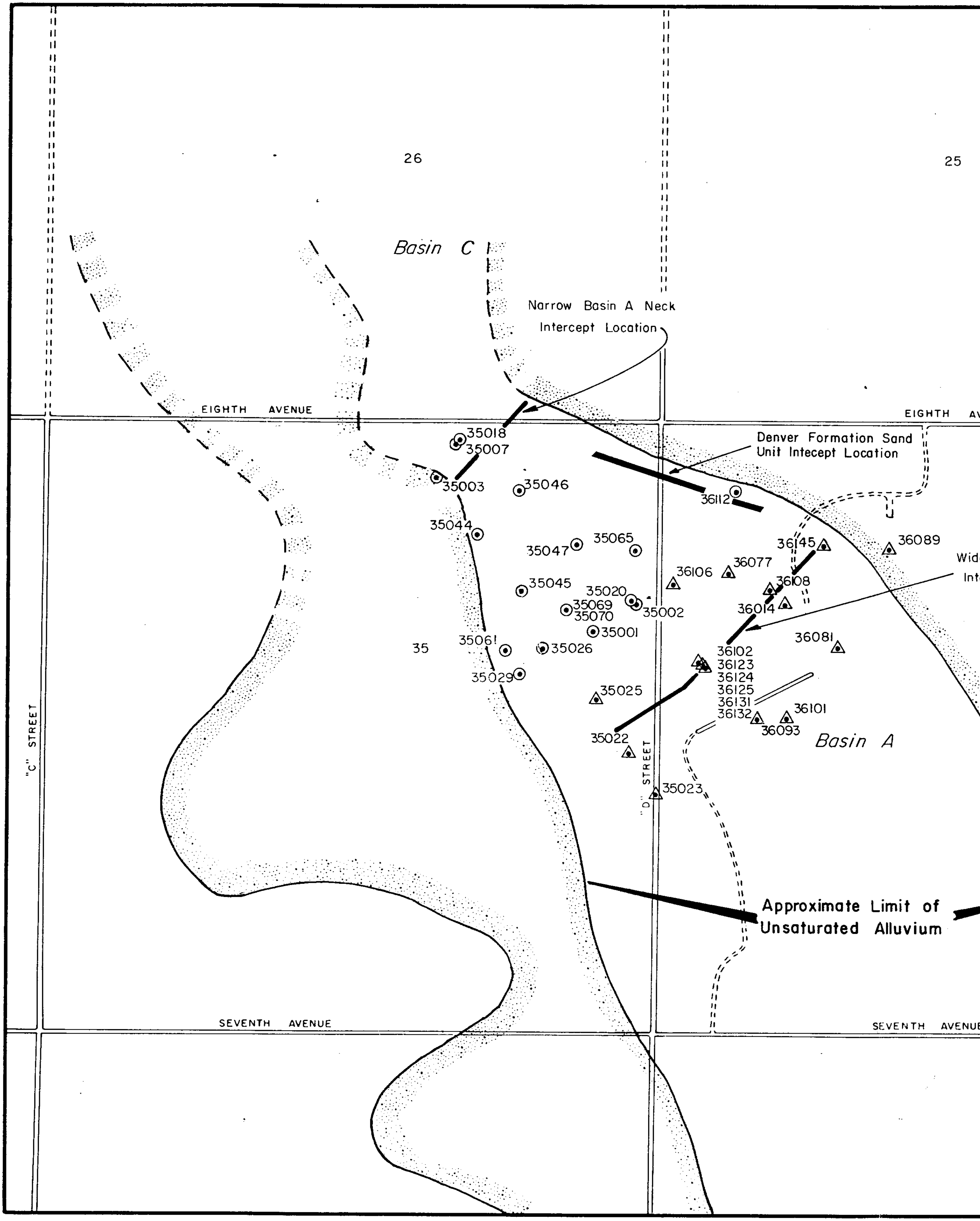
4.3.1 Projected Water Quality

In order to evaluate the groundwater quality in the vicinity of Basin A Neck, groundwater data from alluvial wells were reviewed. Two sets of alluvial wells were evaluated separately in order to characterize groundwater representative of (1) groundwater flowing through the narrowest constriction in the saturated alluvium, and (2) groundwater upgradient in a wider section

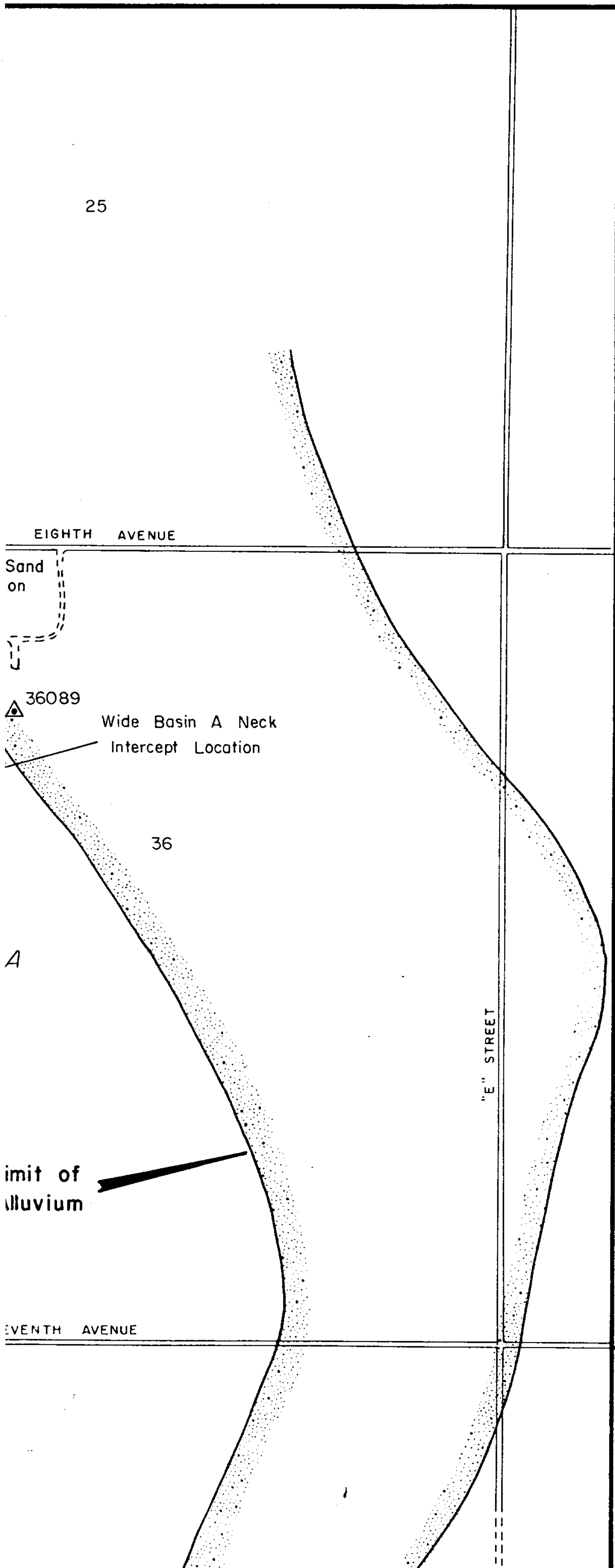
of saturated alluvium. All data were retrieved from Morrison-Knudsen Engineers groundwater quality database (USATHAMA, 1975-1987), the Army's database on the Tentime system (USATHAMA, 1972-1986), and data from Task 4 (ESE, 1987). Only data collected since 1978 were used to ensure that recent trends in the groundwater contamination levels were not inordinately skewed by old data. The data for the two sets of wells are summarized in Appendix A. The term "analytes" as used in this assessment refers to target contaminants, nontarget compounds, and water quality parameters.

The two sets of wells were both defined by northeast and southwest boundaries of unsaturated alluvium. The northwestern set of wells, narrow Basin A Neck, were arbitrarily limited by Eighth Avenue on the north and on the south by a southwest-northeast trending border approximately 1,800 ft southeast of the inferred narrowest constriction in the Basin A Neck, Figure 4-4. This set of wells consists of 16 wells, chosen as representative of alluvial water quality in the narrow Basin A Neck area based on availability of data, screened interval, and date of sampling. A total of 84 analytes were identified. Six of the analytes were identified by retention time and concentration and were not considered in this assessment. Thirty-five of the remaining 78 analytes had no detected concentrations above their reporting levels. The remaining 43 analytes were quantitatively identified as being present at concentrations above their reporting levels.

The southeastern set of wells, wide Basin A Neck, were limited on the north by the same southwest-northeast trending border that defined the southern border of the northwestern set of wells. The southern border of the southeastern set of wells was located approximately 1,700 ft upgradient of the northern border of these wells, Figure 4-4. The southeastern set of wells consists of 18 wells chosen as representative of the alluvial water quality in the wide Basin A Neck area based on availability of data, screened interval, and date of sampling. A total of 73 analytes were identified. Thirty-nine of the analytes had no detected concentrations above their reporting levels. The remaining 34 analytes were quantitatively identified as being present at concentrations above their reporting levels.



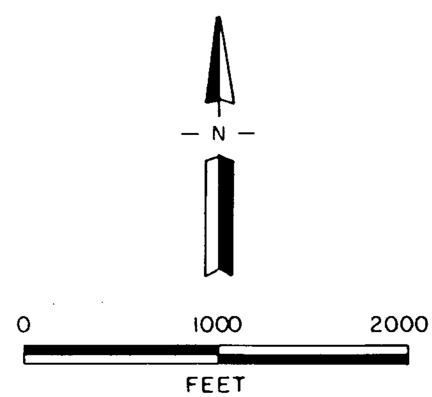
26
25
Basin C
Narrow Basin A Neck
Intercept Location
EIGHTH AVENUE
EIGHTH AV
Denver Formation Sand
Unit Intecept Location
35018
35007
35003
35046
36112
35044
35047
35065
36145
36089
Wid
Int
36106
36077
36108
35045
35020
35069
35070
35002
36014
35001
36081
35
35061
35026
36102
36123
36124
36125
36131
36132
35029
35025
36101
36093
Basin A
35022
"C" STREET
"D" STREET
35023
Approximate Limit of
Unsaturated Alluvium
SEVENTH AVENUE
SEVENTH AVENUE



LEGEND

35018 Alluvial Water Quality Wells for narrow Basin A Neck System

36101 Alluvial Water Quality Wells for wide Basin A Neck System



Prepared for :

Program Manager's Office for
Rocky Mountain Arsenal Cleanup
Aberdeen Proving Ground, Maryland

5/11/88

Figure 4-4

Well Location Map

Rocky Mountain Arsenal

Prepared by : Ebasco Services Incorporated

For both sets of wells, range, mean, and median values were generated from the data for each analyte present at concentrations above its reporting level and are presented in Appendix A. Several data values were considered to be anomalous or outliers and were excluded from the statistical summary. Excluded values are noted in the Appendix. Zero values (below reporting levels) were not used in the statistical summary of the data. Inclusion of zero values would skew the mean and median values downward, while exclusion of zero values from the statistical analysis skews the mean and median values upward and provides a more conservative estimate of water quality. Exclusion of zero values also eliminates or minimizes the influence of data from plume fringes or data from wells outside the plumes.

4.3.2 Target Analytes for IRA Assessment

For the purposes of this assessment, a number of analytes were selected to characterize the aquifer contamination to aid in establishing the suitability of various treatment technologies. These selected analytes are referred to as "target" analytes. Of the 43 chemical analytes reviewed for the narrow Basin A Neck area, 30 were selected as target analytes based on the frequency of detection and/or concentration levels. Fifteen of the compounds were organics and 15 were inorganic or general water quality parameters.

Table 4.3-1 contains a list of the target analytes, the number of hits (number of reported values greater than the reporting level), the number of analyses, the range of hits, and the projected influent value chosen for that compound.

Of the 34 analytes reviewed for the wide Basin A Neck area, 25 were selected as target analytes based on the frequency of detection and/or concentration levels. Fourteen of the compounds were organics and 11 were inorganic compounds or general water quality parameters. The target analytes in Table 4.3-2 are listed with the number of hits, the number of analyses, the range of hits, and the projected influent values. For both sets of data, the median value for each analyte was, in general, lower than the mean value indicating that more data points were present toward the lower end of the reported range.

Table 4.3-1

Target Analytes for the Alternatives Assessment of Alluvial Groundwater Treatment in the Narrow Basin A Neck Area

Organics	Hits/Samples	Range[1] (ug/l)	Projected Influent Value[1,2] (ug/l)
Benzene	6/26	2.4-4.0	3.1
Chlorobenzene	6/27	2.0-6.9	5.0
Chloroform	4/29	2.0-29	10
Chlorophenylmethyl sulfide	6/49	2.6-150	47
Chlorophenylmethyl sulfone	25/57	6.9-7,400	1,000
Chlorophenylmethyl sulfoxide	8/57	9.5-93	46
Dibromochloropropane	20/125	0.19-22	2.1
Dicyclopentadiene	15/99	10-580	90
Dieldrin	9/59	0.072-1.4	0.51
Diisopropylmethyl phosphonate	61/112	2.6-3,000	960
Dithiane	22/57	22-2,900	430
Endrin	7/61	0.30-2.3	0.89
Oxathiane	22/48	8.0-290	58
Tetrachloroethylene	8/26	1.9-22	13
Trichloroethylene	5/18	4.0-8.9	6.7
Inorganics			
Alkalinity ($CaCO_3$)	24/24	51,000-260,000	180,000
Arsenic	7/20	6.0-25	16
Bicarbonate	25/25	120,000-260,000	180,000
Calcium	56/56	31,000-870,000	360,000
Chloride	106/110	23,000-2.8×10^6	840,000
Chromium	5/23	7.3-190	63
Fluoride	57/108	1,100-5,000	2,700
Hardness ($CaCO_3$)	60/60	90,000-6.0×10^6	1.5×10^6

0054Z/0279A
Rev. 9/21/88

Table 4.3-1 (Cont'd)

Target Analytes for the Alternatives Assessment of Alluvial Groundwater Treatment in the Narrow Basin A Neck Area

Inorganics (cont'd)	Hits/Samples	Range(1) (ug/l)	Projected Influent Value(1,2) (ug/l)
Magnesium	54/57	10,000-610,000	190,000
Nitrite, Nitrate	25/43	150-13,000	3,300
pH (3)	62/62	6.3-8.7	7.5
Potassium	57/66	1,400-20,000	8,100
Sodium	95/97	$1,600-2.0x10^6$	690,000
Sulfate	72/73	$78,000-6.8x10^6$	$1.4x10^6$
Zinc	9/15	22-370	110

(1) Range and projected influent values rounded to two significant figures.

(2) Projected influent values for organics and inorganics are mean concentrations except for pH where the median value is used.

(3) Standard units.

0054Z/0279A
Rev. 9/21/88

Table 4.3-2

Target Analytes for the Alternatives Assessment of Alluvial Groundwater Treatment in the Wide Basin A Neck Area

Inorganics (cont'd)	Hits/Samples	Range(1) (ug/l)	Projected Influent Value(1,2) (ug/l)
Benzene	4/10	1.0-21	9.3
Chlorobenzene	2/9	1.0-4.0	2.5
Chloroform	8/9	2.0-1,300	170
Chlorophenylmethyl sulfide	5/38	2.5-18	12
Chlorophenylmethyl sulfone	13/46	19-1100	330
Chlorophenylmethyl sulfoxide	10/46	14-62	34
Dibromochloropropane	10/54	0.61-3.4	1.2
Dicyclopentadiene	4/50	9.0-105	63
Diisopropylmethyl phosphonate	44/56	3.0-41,000	5,700
Dithiane	29/47	5.5-7,000	1,500
Isodrin	4/47	1.1-24	11
Oxathiane	24/39	6.7-840	210
Tetrachloroethylene	4/9	3.0-15	6.9
Trichloroethylene	2/9	2.0-3.0	2.5
Inorganics			
Alkalinity ($CaCO_3$)	9/9	156,000-1.0×10^6	470,000
Calcium	18/18	18,000-1.4×10^6	560,000
Chloride	56/57	68,000-7.6×10^6	2.4×10^6
Fluoride	17/56	1,000-6,000	1,800
Hardness ($CaCO_3$)	9/9	1.0×10^6-4.8×10^6	2.8×10^6
Magnesium	15/17	1,000-630,000	270,000
Manganese	1/1	1,100	1,100
pH(3)	9/9	6.3-7.3	7.0
Potassium	11/11	2,900-30,000	19,000
Sodium	47/47	120,000-4.6×10^6	1.4×10^6
Sulfate	11/11	160,000-1.9×10^6	1.1×10^6

(1) Range and projected influent values rounded to two significant figures.

(2) Projected influent values for organics and inorganics are mean concentrations except for pH where the median value is used.

(3) Standard units.

0054Z/0279A
Rev. 9/21/88

Proposed chemical-specific ARARs for the Basin A Neck area IRA have been included in Table 4.3-3. These ARARs will be used as effluent standards for the treatment system defined during the design phase of this IRA. ARARs are discussed in an accompanying document. Only two inorganic species were identified in the ARARs. Neither inorganic is currently a problem in the groundwater of the Basin A Neck area, therefore, treatment of inorganic compounds will not be considered within the scope of this IRA. Addition of inorganic treatment can be made later if a benefit is identified in the future. However, the inorganic profile of groundwater at this site is relevant to this assessment since inorganics can cause scaling or fouling in certain organic treatment processes.

5.0 TECHNOLOGY ALTERNATIVES

Several response actions in the Basin A area may alter the contamination or flow characteristics of groundwater flowing through Basin A Neck. The influence of these response actions cannot be anticipated, and although they may affect the suitability of some alternatives, they have not been addressed in this assessment.

5.1 HYDROGEOLOGIC ALTERNATIVES

Various extraction and recharge technologies potentially applicable to the Basin A Neck IRA are discussed separately in this section. Barrier systems are also discussed as they may facilitate the extraction process.

5.1.1 Extraction Methods

There are two basic extraction technologies available for the Basin A Neck IRA, pumping wells and subsurface drains. A subset technology to the subsurface drains is an open trench drain. Due to the depth required (over 30 ft), and the problems of keeping a trench open, secure, and operational for extended periods of time, this method does not appear to be feasible and will not be considered in this assessment.

Table 4.3-3

Proposed Chemical-Specific ARARs for the Basin A Neck Area IRA

Analyte	IRA Groundwater Standard (ug/l)
Arsenic	50
Benzene	5
Carbon Tetrachloride	5
Chlorobenzene	488
Chloroform	100
Dichlorodiphenyl trichloroethane	10
1,2-Dichloroethane	5
1,1-Dichloroethylene	7
Dieldrin	0.12
Endrin	0.2
Hexachlorocyclopentadiene	206
Mercury	2
1,1,1-Trichloroethane	200
Trichloroethylene	5

Wells

One method of extracting groundwater is through a series of pumping wells. The wells are installed in a line approximately perpendicular to the direction of groundwater flow, although other patterns can be used for specific purposes. The pumping system can consist of either a vacuum pump or submersible pumps, depending on the depth of the water below ground surface. The pumped water is collected in a header pipe and transported to the treatment system. Because of the low atmospheric pressure at the altitude of RMA and the depth of water below ground surface (10-20 ft), vacuum pumps or suction lifts are not recommended for the Basin A Neck area.

In order to minimize by-pass of contaminated groundwater passing a line of extraction wells, the rate of extraction must cause overlapping cones of depression between adjacent wells. For the wide Basin A Neck location, the aquifer characteristics indicate that a series of 10 to 15 wells spaced at 150 to 200 ft centers should provide sufficient drawdown of the water table to cause overlapping cones of depression. Although the aquifer characteristics of the narrow Basin A Neck location are less well defined, available data indicate that more wells may be required than in the wide Basin A Neck. Actual spacing would depend on the permeabilities, possible use of a physical or hydraulic barrier, and location of the recharge system for the treated water. However, if the net hydraulic conductivity in the narrow Basin A Neck is significantly lower than it is in the wide Basin A Neck, wells may not be a viable option in the narrow Basin A Neck.

Subsurface Drains

Subsurface drains consist of any type of buried conduit that conveys water by gravity flow or pumping. The water is collected in a sump or, if conditions permit, discharged directly to the surface. Drains affect the water table in much the same way as pumping wells, but they create a continuous zone of depression rather than several overlapping cones of depression.

The advantages of subsurface drains are the lower short-term operation and maintenance (O & M) costs compared to pumping wells and the generally greater effectiveness in capturing contaminated groundwater. However, at the depths

required at Basin A Neck, the installation costs for a drain system are higher than for wells.

Using the same aquifer characteristics used for the extraction well system analysis above, a subsurface drain would be a viable option as an interception system. For the narrow Basin A Neck area, a subsurface drain system of the assumed length of 800 ft would be installed to a depth of approximately 27 ft. The wide Basin A Neck area would require a subsurface drain approximately 2,800 ft long installed at an average depth of around 30 ft. A subsurface drain system could be expected to remove groundwater at a rate close to the flow rate through the alluvial channel.

A disadvantage of the subsurface drain system is dealing with the large volume of potentially contaminated material that may be encountered during construction. It is not possible to assess the volume of contaminated soils at this time. Soils removed during excavation activities, either at the surface or subsurface, will be returned in reverse order to the location from which they originated (i.e., last out, first in). Excess excavated soils will have to be checked to determine if they are contaminated or not, and then handled accordingly (USEPA, 1985a). It may be necessary to pump out groundwater encountered during open excavation to allow construction to progress. If so, contaminated groundwater may have to be sent to another treatment facility or stored until this system's treatment facility is operational.

5.1.2 Recharge Methods

There are four basic methods of recharging the groundwater back into the alluvial aquifer:

- o Recharge wells
- o Subsurface drains
- o Pits
- o Leach fields

These are discussed separately. The recharge method need not be the same as the extraction method.

Recharge Wells

Recharge wells return the treated groundwater into the aquifer at a rate equal to the extraction rate. The position of the recharge wells relative to the extraction wells could be selected so as to create a beneficial alteration in the groundwater gradient. Usually this means creating a hydraulic "mound" downgradient of the extraction system to enhance the capture of contaminants by the extraction system. Recharge wells are similar in construction to extraction wells.

A disadvantage of creating a mound downgradient of the extraction system is recycling of treated water from the recharge system to the extraction system. Recycling of treated water would increase the flow through the extraction and treatment systems. This increase in flow would also create an increase in capital and operating costs associated with these systems. In the silts, clays, and sands prevalent in the narrow Basin A Neck, aquifer recharge wells would be difficult to keep operating efficiently and probably would not be feasible.

Problems associated with recharging water in the Basin A Neck can be avoided by recharging farther downgradient in alluvium of a more permeable nature. It is desirable to locate the recharge system in the natural flow path and thereby maintain the local hydrogeologic characteristics. Approximately 1,000 ft downgradient of the narrow Basin A Neck, depth to groundwater ranges from 30 to 40 feet, and present saturated thickness is just a few feet, so much of the alluvium is unsaturated. The water table elevation in this area is over 20 feet lower than the water table elevation in the Basin A Neck, so recharging the treated water downgradient would avoid recycled flow problems.

Recharge wells are used with all three existing RMA boundary containment and treatment systems. Problems with plugging of recharge well screens by carbon fines from the treatment systems have been experienced at the boundary systems (PMSO, 1987a; PMSO, 1987b). Clogging inevitably occurs in recharge systems, but could be reduced with adequate filtration of the treatment system effluent.

Subsurface Drains

A subsurface drain could also be constructed to recharge the treated groundwater. A subsurface recharge drain could mirror a subsurface drain used for extraction or operate in conjunction with extraction wells. The construction of the subsurface recharge drain is similar to the construction of the subsurface extraction drain described previously.

As with the recharge wells, the gravity head alone would be sufficient to recharge water into the aquifer and recharge pumps would not be required. The subsurface drain could be located within a close proximity to the extraction drain to create a hydraulic barrier. Because of the large aquifer area exposed to subsurface drains, plugging with carbon fines would take more time than with recharge wells. However, unlike wells, subsurface drains can not be reconditioned once plugged and must be replaced. As with recharge wells, recharge with subsurface drains close to the extraction system could create a groundwater mound and result in recycle of treated water. The increase in system capacity required to handle the added flow would increase the capital and operating costs of the system.

Pits and Leach Fields

Pits and leach fields rely on the vertical permeability of the soils being sufficient to allow the treated water to infiltrate at an acceptable rate. In the areas of Basin A Neck and downgradient, the vertical permeability through the alluvium is unknown.

Several specific field conditions are helpful in order for pits or leach fields to operate effectively. Conditions that favor the infiltration of water are:

- Sandy material with high permeability;
- The absence of low permeability layers that would impede vertical movement; and
- The absence of layers of significantly higher permeability that would encourage lateral migration over vertical infiltration.

The permeabilities of the alluvial materials in the Basin A Neck area are not well defined. Downgradient, the soils are predominantly sandy, but the presence of silt and clay layers may impede the vertical movement of the water. Further characterization of the alluvial materials is necessary before the suitability of this technology can be fully evaluated.

5.1.3 Barriers

Groundwater control can be enhanced by the use of barriers that stop or impede the flow of groundwater. Barriers are generally either hydraulic and/or physical. Hydraulic barriers are created by adding water to, or subtracting water from, the ambient flow system. Physical barriers are created by changing the permeability of the aquifer by inserting a material with a permeability significantly lower than the natural permeability. Both types of barriers can be used to enhance the capture of contaminants.

Hydraulic

For the conditions that exist in the Basin A Neck, a hydraulic barrier may be well suited to control the migration of contaminants. Hydraulic barriers are created by altering the natural hydraulic flow conditions.

Both extraction systems described in Section 5.1.1 will draw down the water table creating a "trough" that will serve as a barrier to groundwater flow. Locating the recharge system near the extraction system will create a mound that will enhance the effectiveness of this type of barrier. Hydraulic barriers have been incorporated into the Northwest and Irondale Boundary Containment/Treatment Systems.

Physical

Low permeability physical barriers describe a variety of materials that could be installed below ground to reduce or redirect groundwater flow. Slurry walls are less expensive than other subsurface physical barriers and are typically more effective. The most common slurry wall is built with a soil-bentonite slurry. Other types of subsurface barriers (e.g., open cut with clay backfill, cement-bentonite, concrete, asphaltic mixtures) can also be considered, but their higher costs are usually not justified unless

soil-bentonite is inadequate due to water quality compatibility problems. A low permeability synthetic membrane could be used against one side of a trench. This technology may be less expensive than slurry walls, but the feasibility of installing a membrane would need to be evaluated in light of the stability of trench walls and construction methods.

The construction of a slurry wall barrier would require the excavation of a trench an average of 27 ft deep and 800 ft long in the narrow Basin A Neck area. A trench approximately 30 ft deep and 3,000 ft long would be required for the wide Basin A Neck area. The barrier wall should be keyed into impermeable claystone units of the Denver Formation. In an area where a Denver sand unit subcrops beneath the alluvium, a slurry wall barrier may not be feasible as the depth of the excavated trench would be increased substantially. A chemical or grout barrier may be used instead, but detailed aquifer characteristics are needed to assess the viability of the option. Slurry wall barriers have been incorporated into both the North Boundary and Northwest Boundary Containment/Treatment Systems.

A bentonite slurry wall installed between the extraction system and the recharge system serves the purpose of preventing groundwater flow between the two systems. This has the advantage of limiting the recirculation of treated water from the recharge system to the extraction system (May & Miller, 1980). This barrier could also reduce construction and operation costs of the treatment portions of the IRA, depending on the amount of water that would otherwise be recycled between the recharge and extraction systems. Simultaneously, the physical barrier would provide a degree of short-term backup to the hydraulic barrier in the event of a failure (e.g., electrical power outage, etc.). In the event of a long-term shutdown of the extraction system, the barrier would act as a dam to the groundwater flow. Initially, this would not create any problems, but as the groundwater accumulates behind the barrier the backed up groundwater could be released through other mitigation pathways, thus widening the contaminant plume. Subsequent pumping to extract the backed up groundwater could exceed the capacity of the treatment system. Should an alteration of the intercept system be required, such as a variation in the intercept system configuration for the Final

Response Action, the barrier wall could not be easily altered or removed, if at all.

5.2 TREATMENT ALTERNATIVES

A preliminary screening of available technologies has been completed and only those technologies with documented performance and reliability are considered applicable to this IRA.

Treatment technologies can be divided into two groups: those that remove organics and those that remove inorganics. A discussion of treatment technologies appropriate for the removal of organic compounds has been included in this section. As stated previously, inorganic compounds do not currently warrant particular concern other than as possible scaling or fouling problems in organic treatment processes. Inorganic treatment technologies may eventually be required if scaling or fouling problems occur, but these are not discussed in this assessment.

The discussion of each technology addresses such topics as the system operation, required pretreatment, waste streams generated, reliability, design flexibility, complexity, relative cost, and advantages and disadvantages. Many of the processes have been used or tested on groundwater from RMA or on groundwater containing contaminants similar to those found in RMA groundwater. Performance of these methods is included when appropriate.

Activated Carbon

Activated carbon adsorption is the most widely developed and used technology for treating groundwater contaminated with organics. This is an adsorption process in which the raw water is contacted with activated carbon and the organics in the water adsorb to the surface of the carbon. Adsorption is typically conducted in columns.

Adsorption is driven by two factors: the chemical properties of the system (solvent, solute, and carbon) and the physical properties of the carbon. The chemical properties determine the affinity of the solute for the solvent and the affinity of the solute for the activated carbon (Kolmer, 1977). In

general, a polar solute will prefer the phase that is more polar, and a nonpolar solute will prefer the phase that is nonpolar. Thus, a nonpolar solute in a polar phase (such as water) will prefer a nonpolar adsorbent (such as carbon). This condition is conducive to efficient adsorption, and the converse condition would result in low adsorption capacities (Kolmer, 1977).

The physical properties of the carbon are also very important. In general, the surface area and pore structure of the carbon are the prime factors in adsorption of organics from water with the chemical nature of the carbon surface being of minor importance (CDM, 1986). Generally, activated carbon has been found to remove most organic compounds from water with removal efficiencies ranging from 40 to 99 percent, depending on the contaminant characteristics and physical properties of the carbon. However, activated carbon is marginally effective in removing polar compounds such as methylene chloride (CDM, 1986; S-R, 1983).

For design of dynamic adsorption systems, the most important parameters are the adsorption capacity of the activated carbon and the adsorption rates of the contaminants. The capacity is used to estimate the carbon usage rates and the adsorption rates are used to determine the necessary contact time in the adsorption column, referred to as the empty bed contact time (EBCT).

When the effluent quality degrades to an unacceptable level, the carbon must be regenerated or replaced. The frequency of regeneration depends on the incoming water quality. The higher the organic content to be removed, the sooner the carbon will be saturated and need to be regenerated. The frequency of regeneration will dramatically influence the capital and operating costs of the system.

Granular activated carbon is used successfully to treat organics at the North Boundary Containment/Treatment System, the Northwest Boundary Containment/Treatment System, and the Irondale Containment/Treatment System at RMA. Although there have been some reported problems with fine carbon particles from the adsorbers causing plugging problems at the recharge wells, treatment has been satisfactory (PMSO, 1987a; PMSO, 1987b).

The North Boundary System treats higher concentrations of contaminants than the other systems. Dibromochloropropane (DBCP) has been reduced from levels of 6 micrograms per liter (ug/l) to less than the reporting level of 0.2 ug/l. Diisopropylmethyl phosphonate (DIMP) was found as high as 700 ug/l and was generally reduced to less than 50 ug/l. Another contaminant, dicyclopentadiene (DCPD), was reduced from levels of 700 ug/l (and one instance of 1,100 ug/l) to generally less than 10 ug/l. Combined organo-sulfur compounds were found at concentrations of approximately 120 to 150 ug/l in the influent and were below the reporting level in the effluent leaving the plant.

The treatment of contaminated groundwater at RMA using activated carbon has been the focus of various pilot and bench scale testing programs. One program used water from Well 118 (26008) to develop diisopropylmethyl phosphonate and dicyclopentadiene isotherms for 12 commercially available carbons (Thompson & Sweder, 1978). Water from Well 118 was projected to represent groundwater from beneath Basin F. Column studies on this water with a variety of carbons determined that a contact time of 40 minutes was required to reduce the diisopropylmethyl phosphonate concentration from 3000-3600 ug/l to 50 ug/l.

Another study developed isotherms for 18 of 25 RMA contaminants tested to determine the carbon capacity required to treat a mixture of contaminants (Walters, undated).

A pilot plant was operated in 1983 to analyze the performance of various treatment technologies on groundwater from the South Plants area (S-R, 1983). Two carbon adsorbers were included in the South Plants Groundwater Treatment Pilot Plant and were used in several tests. The columns were used to treat raw water and water that had been pretreated with an air stripper. It was concluded that in the presence of very high organic content, granular activated carbon by itself would not be cost effective. When the water was pretreated with the air stripper, scale buildup on the carbon was a problem. During the latter test, the pH of the raw water rose from 6.9 to 8.1, causing a corresponding shift in the Langelier Index from -0.2 to 1.0 and the Rynzar

Index from 7.3 to 6.1. In both cases, this indicated a shift from corrosive to scale forming tendencies.

Test results showed breakthrough for chloroform at a carbon loading of about 0.75 pounds (lb) of chloroform per 1,000 lb of activated carbon (750 micrograms per gram (ug/gm)). Breakthrough for dimethyldisulfide (DMDS) was noted at about 0.10 lb of dimethyldisulfide per 1,000 lb of activated carbon (100 ug/gm), and breakthrough for methylene chloride was observed at about 0.02 lb of methylene chloride per 1,000 lb of activated carbon (20 ug/gm). Some leakage of methylisobutyl ketone (MIBK) and pesticides was attributed to inconsistencies in the carbon bed. An empty bed contact time of 30 minutes was maintained throughout the test program. The groundwater treated in these tests contained more organics than the groundwater in the alluvial aquifer in the Basin A Neck area.

In general, activated carbon systems are not complex and are easy to operate. Capital and operating costs for activated carbon systems are moderately high, relative to other treatment technologies. The need to regenerate the carbon is the most costly aspect of carbon adsorption.

Advantages of an activated carbon system are:

- Well documented and utilized;
- Simple operation; and
- The ability to remove mixtures of organics.

Disadvantages include:

- Moderately high capital and operating costs;
- Very expensive regeneration; and
- If not regenerated, the spent carbon may require disposal as a hazardous waste.

<u>Air Stripping</u>

Air stripping is an effective and proven way to remove volatile organic components from groundwater. It is the process of transferring a contaminant

from a liquid phase to a gas phase. In the treatment of groundwater, the raw water is brought into contact with air, and volatile components in the water transfer across the water/air interface into the air. For this to occur, the water must contain the volatile species in excess of equilibrium, and transfer will continue until equilibrium is reached. If the air is continuously replaced with fresh uncontaminated air, and if sufficient contact time is allowed, all of the volatile components will be removed from solution. Nonvolatile organic compounds are not easily removed by air stripping (CDM, 1986).

The tendency for chemical species to transfer from the water to the air phase is often stated in terms of the Henry's Law constant for that specie. Henry's Law states that the concentration of a gas dissolved in a solvent (the amount of contaminant dissolved in the water) is directly proportional to the partial pressure of the gas (contaminant) in contact with the solution (Sienko & Plane, 1974). The proportionality constant, the ratio of vapor concentration to liquid concentration, is the Henry's Law constant. The higher the Henry's Law constant the more easily the compound is stripped (Conway & Ross, 1980). In general, organic compounds can be stripped from water if the dimensionless Henry's Law constant for that compound is above 0.003 (USEPA, 1983).

In general, water entering the air stripper is not pretreated, although filtering may be required if the total suspended solids content is excessive. The waste stream generated by an air stripping unit is the air containing the stripped species. If these compounds are present in low concentrations, the air can be discharged directly to the atmosphere. If air emission standards are exceeded, the exhaust air is normally either incinerated or run through a vapor phase carbon adsorption unit to remove the contaminants. This requirement will add significantly to the capital and operating costs of the facility.

The most commonly used, efficient, and economical air stripping system is the packed tower system (CDM, 1986). The tower is packed with material having a very high surface area and void space per unit volume. The water is trickled down the packing while air is passed through the packing by use of a blower.

Air:water ratios commonly employed range from 25:1 to 250:1 (Nyer, 1985). Contaminated air is exhausted from the top of the column and treated water is discharged at the bottom of the unit. If the discharged air does not meet air pollution standards, additional treatment can be added to the column.

The South Plants groundwater treatment pilot plant included an air stripper that showed removal rates of 96 to 100 percent for volatile organic compounds except for methylisobutyl ketone and carbon tetrachloride (S-R, 1983). Tests on this unit also showed that no particular advantage was gained by softening the water prior to treatment and that increasing the air to water ratio increased the removal of all volatile organic compounds.

Air strippers have been used at many sites to effectively remove volatile chlorinated solvents from drinking water supplies (Thibodeaux, 1985). The process is simple to operate and relatively inexpensive to install and run.

Advantages of the air-stripper method are:

- o Moderately low capital and operating costs; and
- o Simple to operate.

Disadvantages of this method are:

- o Incomplete removal of nonvolatile organics; and
- o Air emission control equipment may be required.

Biological Treatment

Biological treatment removes organic contaminants through microbial assimilation and degradation. Biological systems can also be utilized to remove some inorganics, such as ammonia and nitrate, from groundwater. The most widely used forms of biological treatment are aerobic systems, although anaerobic systems are also very effective. Biological treatment systems may also be classified as either fixed film systems or suspended growth systems, depending on whether the microorganisms are grown on a surface or suspended in the water. Activated sludge systems are the most commonly used aerobic

suspended growth systems. Examples of aerobic fixed film systems include trickling filters and rotating biological contactors.

Despite the fact that some wastes (e.g., certain organic compounds and heavy metals) inhibit biological treatment, the biomass can be acclimated, within limits, to tolerate elevated concentrations of the contaminants (USEPA, 1985b). Several factors influence performance of this treatment process, such as the concentration of suspended solids, organic load variations, oil and grease, pH, alkalinity, acidity, phenols, sulfides, ammonia, and temperature; thus, some pretreatment may be necessary for effective results. Biological treatment systems can be very effective, are generally easy to operate, have low capital and operating costs and are somewhat self-regulating. The waste side streams consist of excess biomass that is generally nontoxic.

Biological treatment was tested in a pilot study at RMA by the Shell Development Company (Rezai, 1982). Very good results were achieved when the system was operated as an activated sludge system. The major contaminants of concern in this study were chloroform, benzene, and dibromochloropropane. After steady state operation was established, 99.7 percent of the benzene was removed, 91.5 percent of the chloroform was removed, and 96.1 percent of the dibromochloropropane was removed. Daily supplements of ammonium and phosphorus were added to maintain a nutrient-balanced feed.

Basin A Neck groundwater contains chlorinated pesticides that are designed to be persistent in the environment. Biodegradability tests using static-culture shake flasks containing yeast extract and 5 and 10 mg/l of aldrin, dieldrin, and endrin individually found no biodegradation of the pesticides in four consecutive 7 day incubation periods (Tabak et al., 1981). The authors noted that this confirmed other results found in the literature. The U.S. Environmental Protection Agency investigated the treatability of select toxic pollutants and found that biodegradation was not a significant removal mechanism for aldrin, dieldrin, and endrin (USEPA, 1980a). However, at least one study (Matsumura et al., 1978) has indicated that soil microorganisms are capable of biodegrading chlorinated hydrocarbons. Other studies (Bouwer & McCarty, 1984; Bhattacharya & Parkin, 1988; Wilson, 1981) indicate some

halogenated organics degrade more rapidly in anaerobic environments than in aerobic environments although often at very slow rates.

Advantages of biological treatment include:

- o The adaptability of the process to a variety of contaminants;
- o The somewhat self-regulating feature;
- o Side streams are generally nontoxic; and
- o The process has low capital and operating costs.

Disadvantages include:

- o The process requires a relatively constant quantity and quality of feed stream;
- o The process is subject to upsets and toxicity problems;
- o The process may not be effective for all of the organic compounds present; and
- o Extensive pilot testing would be required.

<u>Evaporation</u>

Evaporation is a process in which volatile liquids are removed from a waste stream, leaving behind less volatile components. This process is generally used to remove inorganic components from water. Organic compounds can be removed with evaporation; highly volatile species can be volatilized or nonvolatile species can be concentrated. Open ponds are commonly used treatment systems in these cases.

Solar evaporation ponds can be quite inexpensive, although if the liquid is considered to be hazardous, a double liner with an intermediate leachate detection system is required (COE, 1987b). A further consideration is the potential requirement to replace evaporated water for recharge. Water vapors could be contained and condensed or make-up water could be purchased from a municipality.

Although a liquid side stream of contaminants is unlikely, vapor or concentrated sludge side streams may be produced.

Some advantages of an evaporation system are:

- A solar evaporator has low capital and operating costs; and
- A solar evaporator requires no operators.

Some disadvantages are:

- Volatilized organics may require expensive emission controls;
- Liquid or solid contaminant concentrates requiring treatment or disposal may be produced;
- Evaporated water may need to be replaced for recharge to the aquifer; and
- Solar evaporators are dependent on the weather and may take an unacceptably long time to complete the process.

Oxidation

Oxidation refers to the process of destroying organic matter in a contaminated stream by chemical or thermal means. The products of complete hydrocarbon oxidation are water and carbon dioxide.

Thermal methods of oxidation, such as incineration, are generally not suited for dilute liquid waste streams due to the large amount of energy required to vaporize the bulk liquid. For dilute liquid streams, chemical oxidation is generally preferred. Three commonly used chemical oxidation processes are: ozonation, hydrogen peroxide, and potassium permanganate. Oxidation is generally not specific to one compound over another and all oxidizable compounds are attacked to varying degrees.

Of the three common oxidizing agents (ozone, hydrogen peroxide, and potassium permanganate), ozone is the most powerful oxidant and can therefore achieve the greatest removal percentages (McShea et al., 1986). However, ozone by itself usually cannot achieve quantitative removal of organics without excessive reaction times or ozone dosages (COE, 1987b).

The presence of ultraviolet (UV) radiation catalyzes the reactions and thereby reduces the reactor volume and chemical requirements. As a general rule, the higher the total organic carbon (TOC), the more oxidant and UV energy

required. The actual removal rate for various compounds depends on how easily that compound is oxidized and how readily it absorbs UV radiation (COE, 1987b). The final oxidation products generally do not need to be removed from the treated water; thus, no contaminated waste streams are generated by the process.

Performance can be increased by keeping the UV bulbs free of scaling and by reducing the turbidity of the water (COE, 1987b). Both of these actions will ensure good transfer of the UV energy to the bulk of the water. Pretreatment can include water softening to reduce scaling problems and filtration to reduce turbidity.

A laboratory bench scale study has been performed to test the efficiency of UV/ozone on groundwater from Well 118 (Khan & Thompson, 1978). Pretreatment to primarily remove iron and manganese was required to avoid interfering with the transmittance of the UV light. The diisopropylmethyl phosphonate concentrations were reduced from influent concentrations of 2,300 to 4,300 ug/l to less than 500 ug/l after contact times of 3 to 4 hours.

The study by Sirrine, Inc. for the Corps of Engineers (COE, 1987b) found references to several successful applications of the UV/ozone oxidation treatment process. Dibromochloropropane was removed to below detectable limits in the treatment of a chemical plant wastewater (Zeff et al., 1983), and polychlorinated biphenyls (PCBs) were removed in the secondary effluent of a capacitor manufacturer (Arisman, 1980). Groundwater contaminated with pentachlorophenol and creosote is also being treated successfully (COE, 1987b).

Ozone oxidation with and without the addition of UV energy was investigated for treatment of wastewater generated at the hydrazine blending and storage facility (Ebasco, 1988). The wastewater contained hydrazine, unsymmetrical dimethylhydrazine (UDMH), and monomethylhydrazine (MMH). A further consideration in the oxidation of hydrazine is the production of N-nitrosodimethylamine (NDMA), which occurs as a breakdown product of hydrazine and that also must be destroyed.

Without UV energy, the hydrazine, monomethylhydrazine, and unsymmetrical dimethylhydrazine were destroyed to concentrations below reporting levels of 5 parts per million (ppm), 50 parts per billion (ppb), and 10 ppb, respectively. The N-nitrosodimethylamine that was produced (approximately 150 ppm) was oxidized to less than 2.4 ppb in 20 hours.

Oxidation with the addition of UV energy was also investigated. Research and pilot testing have shown that hydrazine, unsymmetrical dimethylhydrazine, and monomethylhydrazine are rapidly oxidized with this system, and N-nitrosodimethylamine has been oxidized to below a reporting level of 16 parts per trillion (ppt). In addition, miscellaneous by-products of ozonolysis have been shown to be readily destroyed by UV light.

The South Plants Groundwater Treatment Pilot Plant investigated the efficacy of ultra violet/hydrogen peroxide (UV/H_2O_2) oxidation on groundwater from South Plants (S-R, 1983). The variables of concern in the tests were the residence time, hydrogen peroxide dosage, and pH. The ultraviolet energy input averaged about 450 watts/gallon of groundwater. The amount of pretreatment was varied and included no pretreatment, air stripping as pretreatment, and air stripping plus the addition of 1 percent pig stomach catalase enzyme. During the tests, it was found that the water heated up considerably due to the UV energy being added. This is something that would have to be addressed if a permanent system were installed.

The results of the test showed that, in general, oxidation was faster at low pH (about 4) than at high pH. Complete oxidation of organics in the feed stream took 2 hours. Higher organic loadings required higher hydrogen peroxide dosages and longer residence times. Addition of a catalyst ($FeSO_4$ $7H_2O$) improved oxidation rates. The final recommended operating conditions were a retention time of 120 minutes and pH of 4. Hydrogen peroxide dosages were recommended at 500 to 1,000 ppm, depending on the total concentration of organics.

Oxidation processes are relatively easy to operate, although the capital and operating costs are high. Additional considerations regarding the UV-ozone treatment process are the possibility of incomplete oxidation of all organic contaminants or of encountering particularly recalcitrant compounds that resist degradation. In addition, both pretreatment and post-treatment may be required to ensure complete removal of contaminants. In any case, pilot testing to determine optimum operating conditions for the incoming water quality would be necessary.

Some advantages of the oxidation processes are:

- The ability to achieve virtually complete destruction of toxic organics;
- No waste side streams; and
- Relative ease of operation.

Disadvantages include:

- High capital and operating costs;
- Possible requirement for pretreatment; and
- Possible requirement for post treatment of oxidation products.

<u>Reverse Osmosis</u>

Reverse osmosis is a membrane separation process that can reduce concentrations of dissolved organic and inorganic compounds and ions by 90 percent or more (Jhawar & Sleigh, 1975). Osmosis is the natural tendency of water to pass through a semi-permeable membrane from the weak solution side to the strong solution side. Pump pressures can be applied to reverse this process and force water from the concentrated side to the pure (permeate) side. The performance of reverse osmosis systems is strongly influenced by the type and configuration of the membranes being used. Pilot testing is often required to determine the best system design for a particular waste stream.

Deterioration of the membranes through chemical attack and fouling and plugging of the flow system may make pretreatment necessary. Pre-filtration to at least 5 microns is generally required, and chloride concentrations above 10,000 mg/l may cause corrosion of the process equipment (COE, 1987b). The quantity of the side stream produced by this process is about 5 to 30 percent of the feed stream.

Reverse osmosis is most often used for inorganic treatments, such as desalination, and a system was evaluated for inorganics removal as part of the South Plants Pilot Plant Study (S-R, 1983). It was determined that the system did remove some, though not all, of the chloroform that had passed through the pretreatment processes.

Treating organics with reverse osmosis poses different problems than treating inorganics. Organics tend to adsorb to the membrane surface as much as they are rejected into the concentrated stream. Also, membranes generally only stop compounds having molecular weights larger than 150 to 200. A high total dissolved solids (TDS) content will lead to a large reject stream that would require further treatment (COE, 1987b).

The primary advantage of the reverse osmosis process is:

- The ability to remove organic molecules with a molecular weight greater than 200, inorganics, and metals.

Disadvantages include:

- The requirement for extensive pretreatment, depending on waste characteristics;
- A membrane life of 2 to 3 years;
- High capital costs;
- The requirement for sophisticated control equipment; and
- The production of a concentrate stream that would require treatment and disposal.

Ultrafiltration

Ultrafiltration is a form of filtration that is appropriate for removal of some organics. An ultrafilter is a porous membrane that is permeable to some compounds and impermeable to others. In addition to removing very small particulate matter, the process is also applicable for organic molecules generally ranging in size from 500 to 500,000 molecular weight (Weber, 1972). Removal of a substance is related to its molecular shape, size, and flexibility.

Ultrafiltration is similar to reverse osmosis except that much lower feed pressures are used, usually in the range of 5 to 100 pounds per square inch (psi). The process produces a concentrated waste stream that is usually less than 5 percent of the influent volume. As a filtration technique, ultrafiltration is very expensive due to its large particulate pretreatment requirements and its membrane costs. However, it is a very effective process for removing many large organic molecules.

Advantages of the ultrafiltration process are:

- The ability to remove large organic molecules; and
- A lower operating pressure than reverse osmosis.

Disadvantages are:

- Small organic molecules are not removed; and
- High capital and operating costs.

6.0 SYSTEM ALTERNATIVES

6.1 NO ACTION ALTERNATIVE

Although the No Action alternative is normally evaluated as part of the alternatives evaluation phase of both interim and final response actions at CERCLA sites, Paragraph 9.1 of the proposed Modified Consent Decree (1988) states that the IRAs for Rocky Mountain Arsenal have been determined to be both necessary and appropriate. Therefore, this alternative will not be considered in this assessment. Determination to proceed with this IRA will be made in the decision document.

6.2 HYDROGEOLOGIC ALTERNATIVES

As presented in Section 4.2, the hydrogeologic conditions of the Basin A Neck area are very complex. The two locations to be evaluated for the intercept system are the narrow Basin A Neck area and the wide Basin A Neck area (see Figure 4-1).

6.2.1 Alternatives Screening

Subsurface drains appear to be a feasible extraction technology for both potential system locations. Drain systems are applicable to both low and high permeability aquifers.

Wells would be the preferred extraction technology as they are generally less expensive to install than subsurface drains; however, wells are generally not applicable to lower permeability aquifers. Aquifers with low permeability materials require many closely spaced wells to adequately control the contaminated groundwater flow. More wells result in increased system capital costs and increased operation and maintenance costs, especially for low flow systems. Based on current information, wells are feasible for the wide Basin A Neck but may not be feasible for the narrow Basin A Neck.

As indicated in Section 4.2, the effective permeability of the alluvium in the narrow Basin A Neck could be greater than currently estimated if the lenses of permeable material are more extensive than presently defined. Aquifer tests should be conducted in this area to determine if wells would be a feasible and less costly extraction alternative. A remote component to a narrow Basin A Neck system may be required to capture contaminated flow migrating laterally from the alluvium to Denver Formation sand units on the northern edge of the Basin A Neck. This component of the extraction system would not be required for the wide Basin A Neck location because a treatment system at that location would be upgradient of the subcropping Denver Formation sand units.

Subsurface drains are also feasible as recharge alternatives for both possible system locations. Subsurface recharge drains located downgradient and adjacent to the extraction system would enhance the hydraulic barrier of the extraction systems by producing a groundwater mound. The drains could also

recharge at a location remote from the extraction system. Any groundwater mound formed would have no effect on the extraction system and recycle of treated water would be eliminated.

Wells could be used to recharge the treated water if the alluvial materials are sufficiently permeable to prevent the recharge mound from reaching the ground surface. The low permeability of the alluvium immediately downgradient of the wide Basin A Neck location and in the narrow Basin A Neck location may eliminate this technology for these sites. Although preferred, a hydraulic barrier is not required, and recharge wells could be used downgradient where the alluvium is more permeable.

Leach fields may be feasible as recharge options in the two Basin A Neck locations, although the permeability of the alluvial materials must be further characterized before it is known for certain. They would be feasible technologies for remote recharge of the treated water downgradient. However, former disposal basins, such as Basin C, would not be preferred disposal sites for near-surface recharge systems. This technology may be the least costly option available, although there are possible freezing and other operational problems.

A physical barrier could be included downgradient of the extraction system to enhance the capture of contaminants, provide for short-term storage of contaminated groundwater in the event of a system shut down, and minimize the amount of treated water recycled to the extraction system. However, for this IRA, the economic benefits of reducing the recirculation of treated water may not offset the costs of constructing a physical barrier. Additionally, a physical barrier could not be modified or eliminated easily should the Final Response Action for this area be significantly different from the IRA. Additional aquifer data will be needed and designs considered before a final decision should be made concerning the use of a physical barrier. Use of a physical barrier should be considered only if other technologies do not meet the needs of this IRA.

6.2.2 Alternatives Evaluation

There are 20 potentially applicable groundwater intercept systems for the Basin A Neck IRA. A thorough characterization of the flow rates, permeability, and near-surface contamination in the Basin A Neck area may significantly reduce the number of feasible system alternatives. Table 6.2-1 lists the extraction and recharge technologies and approximate capital costs of each technology for the two system locations. The extraction and recharge technologies may be combined to establish the most feasible and efficient system. All technologies listed are potentially applicable to both the narrow and wide Basin A Neck locations. Cost estimates are also provided for physical barrier walls.

The cost estimates presented in this table do not include costs for disposal of contaminated material generated during construction as the volume of contaminated material is unknown. These disposal costs would primarily be associated with construction of subsurface drains and physical barriers.

The extent of the lateral Denver Formation sand units in the narrow Basin A Neck has not been established. Without this information, there are insufficient data to develop cost estimates for a remote intercept system in that area. Costs presented in Table 6.2-1 do not include the costs of a remote system. The cost estimates for narrow Basin A Neck systems should be higher than those indicated in Table 6.2-1. Cost estimates provided should be examined comparatively. Costs may change significantly as hydrogeologic conditions in the Basin A Neck become better defined. Section 8.1 identifies the additional information required prior to selecting a system location and appropriate technologies. Cost considerations will remain secondary to technical considerations in the intercept system selection process until a better understanding of the feasibility of the hydrogeologic alternatives is achieved.

6.3 TREATMENT ALTERNATIVES

6.3.1 Alternatives Screening

Implementing the chosen treatment process in a timely manner is a major concern. The treatment alternatives will be screened based on the ability to

Table 6.2-1 Potentially Applicable Extraction and Recharge Technologies[1] and Capital Costs[2] for the Basin A Neck IRA.

Narrow Basin A Neck[3]

EXTRACTION	RECHARGE
Subsurface Drains $ 450,000	Adjacent Subsurface Drains $ 460,000
Wells $ 160,000	Remote Subsurface Drains $1,000,000
	Remote Wells $ 370,000
	Adjacent Leach Fields $ 210,000
	Remote Leach Fields $ 360,000

Wide Basin A Neck

EXTRACTION	RECHARGE
Subsurface Drains $2,300,000	Adjacent Subsurface Drains $2,300,000
Wells $ 280,000	Remote Subsurface Drains $1,000,000
	Remote Wells $ 370,000
	Adjacent Leach Fields $ 210,000
	Remote Leach Fields $ 360,000

Barrier wall at the wide Basin A Neck location: $1,392,000

Barrier wall at the narrow Basin A Neck location: $ 330,000

1. The most feasible extraction and recharge technologies will be combined to form the groundwater intercept system.

2. Operating and maintenance costs are not expected to be significant in cost comparisons.

3. Costs of a remote intercept system have not been included.

0054Z/0279A
Rev. 9/21/88

remove organics and the time required to install the process. Inorganic species are of concern only with respect to possible scaling and fouling problems in the process equipment. The need for pretreatment for hardness, manganese, and scaling compounds will be dictated by the ability of the chosen treatment processes to operate with hard water. Possible treatment technologies will be discussed in the same order as they were presented in Section 5.2.

Carbon adsorption is a proven treatment process for removal of organic compounds, although it will not remove polar compounds such as methylene chloride very efficiently. Activated carbon systems are not complex, are easy to operate, require no pilot studies, and could be implemented quickly.

Air stripping is a proven technology for removal of organics from water. Removal of contaminants by air stripping, however, requires that the compounds be relatively volatile. Compounds with Henry's constants equal to or greater than that for chloroform ($H = 2.9\times10^{-3}$ atm-m^3/mol) would be considered easily strippable. Air stripping of less volatile compounds may require very high air/water ratios, and compounds of low volatility will not be removed in this process.

The only compounds in groundwater from the wide Basin A Neck area that would be efficiently removed in an air stripper are chloroform, methylene chloride, tetrachloroethylene, and trichloroethylene. The three latter compounds are present only at low ppb concentrations. The removal of these compounds in an air stripper would not justify the added complexity and costs of the system. Volatiles at low concentrations could be removed by activated carbon adsorption units.

The concentration of volatile organics in groundwater from the narrow Basin A Neck area is even lower than in the wide Basin A Neck area and too low to make air stripping a viable treatment alternative.

Biological treatment systems require the total organic carbon concentration to be fairly constant, a condition that is usually met with groundwater. Also, a minimum total organic carbon concentration in the water is needed to sustain the microorganisms. Water quality data indicate that the total organic content in groundwater from the Basin A Neck area is too low to sustain a sufficient quantity of biomass needed to make biological treatment feasible (COE, 1987b). In addition, not all of the compounds present are readily treatable with biological systems, particularly the pesticides. While treatment of these organics may be feasible, considerable time would be spent in developing and demonstrating an effective biological treatment system. It does not appear that biological treatment would be a viable alternative for this groundwater.

Although evaporation can treat dilute streams, it is best suited to treat concentrated streams, such as side streams generated by other treatment processes. The time and energy or size requirements of evaporation units for dilute systems are often prohibitive. To treat the entire extracted stream with evaporation would be much too expensive to be done in a mechanical evaporator. A solar evaporator for the same stream would require roughly 15 acres and would be controlled primarily by the weather, not by site personnel. Any water lost to the atmosphere may have to be replaced with purchased water. An evaporated stream may require expensive air emission controls. Liquid or solid side streams containing contaminant concentrates may require treatment or disposal. In light of these considerations, evaporation should not be considered.

Although a promising technology, chemical oxidation would require extensive pilot testing to determine optimum operating conditions, to verify that target compounds were being destroyed sufficiently, and to identify process effluents. Operating costs and pretreatment requirements cannot be estimated at this point. Because the uncertainties related to this process, this technology would not be recommended for use in the Basin A Neck groundwater treatment system.

Reverse osmosis is a proven technology for removing organics with molecular weights down to about 150 to 200. The target compounds include compounds with molecular weights both above and below this range (COE, 1987b). This means that, unless they were adsorbed by the membrane, dicyclopentadiene and diisopropylmethyl phosphonate and the lower molecular weight compounds would partition to the permeate while aldrin and dieldrin would be found in the concentrate. The required removal efficiencies would consequently not be obtained by reverse osmosis for most of the compounds in Basin A Neck groundwater. In addition, extensive pretreatment would be required, pilot studies would be necessary, and capital and operating costs would be very high. Reverse osmosis is consequently eliminated from further consideration.

Ultrafiltration is best used to remove large organic molecules having molecular weights greater than 500. The compounds of concern in Basin A Neck groundwater are all smaller than that and are likely to pass through the membrane; therefore, ultrafiltration is not appropriate for this system.

6.3.2. Alternatives Evaluation

Based on the above discussion, carbon adsorption is the technology best able to remove target compounds in the groundwater of Basin A Neck. Carbon adsorption is a proven technology at RMA and is capable of removing the compounds of concern. It should be noted that selection of flow rates, carbon adsorption vessel sizing, activated carbon usage rates, etc., will occur during preparation of the final design and that the values discussed in these paragraphs are for purposes of developing preliminary cost estimates and for assessing feasibility.

All the compounds of concern in groundwater from the narrow Basin A Neck area are efficiently removed by activated carbon adsorption. The carbon use rate for this system is assumed to be 1.5 lbs of carbon per 1,000 gallons of water treated since the contaminants are fairly well adsorbed. An adsorber containing 2,000 lbs of carbon would be exhausted every 62 days at a flow rate of 15 gpm.

Groundwater from the wide Basin A Neck area has a higher concentration of organics, including 170 ug of chloroform. By using isotherm data for chloroform (USEPA, 1980b) the regeneration interval was estimated to be 46 days for a 2,000 lb adsorber and a flow rate of 15 gpm. This corresponds to a carbon use rate of approximately 2 lbs per 1,000 gallons.

There is a possibility that the hardness of the water would cause precipitation of calcium, magnesium, and manganese salts on the carbon. If necessary, this problem could be resolved by pH adjustment in the form of acid addition to the feed water. This form of pretreatment should reduce scaling with minimal cost increase.

Preliminary estimates of costs associated with the carbon adsorption systems are presented in Table 6.3-1. Costs presented in this table exclude facility costs.

7.0 DESCRIPTION OF SYSTEMS

7.1 HYDROGEOLOGIC SYSTEM

If further characterization of the hydrogeology in the narrow Basin A Neck indicates that wells are a feasible extraction method and will capture most of the alluvial flow passing through the wide Basin A Neck, then an intercept system in the narrow Basin A Neck would be the preferred alternative. For a system in the narrow Basin A Neck to be feasible, the alluvial materials at that location must be permeable enough to allow development of overlapping cones of depression. All else being equal, the cost of an extraction well system in the narrow Basin A Neck should not exceed the cost of an extraction well system in the wide Basin A Neck. A system using extraction wells in the wide Basin A Neck would be preferred if a system in the narrow Basin A Neck proves not feasible, or is too costly, or does not capture most of the flow in the wide Basin A Neck.

Adjacent or remote leach fields or remote wells would be the preferred methods of recharge depending on near-surface contamination and vertical permeability of the recharge site.

TABLE 6.3-1 TREATMENT SYSTEM COST SUMMARY*

Alternative I: Activated Carbon Adsorption System for Narrow Basin A Neck

CAPITAL COSTS

Two Skid-mounted Adsorption Vessels Including Carbon	$46,000
Influent and Backwash Pumps	3,000
Filter	2,000
Other Scope Items (20%)	10,000
Design (12%)	7,000
Contingency (15%)	10,000
	$78,000

OPERATING COSTS

Carbon Regeneration and Replacement	$12,000
Electricity	3,000
Labor	10,000
Monitoring	50,000
Maintenance	2,000
	$77,000

Alternative II: Activated Carbon Adsorption System for Wide Basin A Neck

CAPITAL COSTS

Two Skid-mounted Adsorption Vessels Including Carbon	$46,000
Influent and Backwash Pumps	3,000
Filter	2,000
Other Scope Items (20%)	10,000
Design (12%)	7,000
Contingency (15%)	10,000
	$78,000

OPERATING COSTS

Carbon Regeneration and Replacement	$16,000
Electricity	3,000
Labor	10,000
Monitoring	50,000
Maintenance	2,000
	$81,000

* Costs were obtained from the following vendors:
Carbon system (Wood, 1988), Filter (Evans, 1988).

For the IRA, the cost of a physical barrier wall does not seem justified in either the narrow or wide Basin A Neck locations. A system without a barrier wall in the wide Basin A Neck would be more cost effective than a system in the narrow Basin A Neck with a barrier wall.

The use of a hydraulic barrier, while preferred to minimize by-pass of contaminated groundwater, is not required. The exact location, number, and spacing of wells or other technologies used for extraction or recharge should be determined in the design phase of the IRA.

7.2 TREATMENT SYSTEM

For the purposes of this assessment, to effectively treat the groundwater from Basin A Neck with simple, proven technology and with minimal delays, carbon adsorption systems are recommended. It is recommended that two activated carbon adsorption units operated in series be used for either proposed system location, and that the adsorber effluent is filtered to remove carbon fines and minimize clogging of the recharge system.

Support units to the treatment process would also be needed. A sump would be required to equalize influent groundwater concentrations and flow. The treatment system should be enclosed to prevent icing problems during winter operations and should be sized to permit additional pilot testing, if desired. The technology selected has been proven effective and reliable off-site and on RMA with RMA-specific contaminants. The system described should have a lifetime of at least five years and be able to handle a variable flow stream. The system must be readily expandable to include more units or alternate technologies in support of, or for inclusion in, the Final Response Action.

8.0 DATA GAPS

Specific definition of the system presented in this assessment will require the collection of additional information as described in the following sections.

8.1 HYDROGEOLOGIC SYSTEM

A summary of data needs for the groundwater extraction system includes:

- o A site-specific characterization of the hydrogeologic conditions in the area of Basin A Neck, including vertical and areal permeability, flow rates, near-surface contamination, and their effect on design parameters;
- o A definition of the contaminant plume based on specific chemical concentrations; and
- o An evaluation of the potential influence of the Denver sand units subcropping beneath and lateral to the Basin A Neck on groundwater and contaminant flow.

The hydrogeologic conditions in the area of Basin A Neck are not fully characterized at this time. Currently available data allow for some understanding of the hydrogeologic regime, but specific information about possible locations to be selected for the intercept system lacks sufficient detail. For example, the locations of suitably permeable zones are not known with sufficient accuracy to allow an extraction system to be located in the zone of maximum permeability. For a system to be effective, this information is essential. If the extraction system is located in an area of low permeability or low saturation, it will not function properly.

The necessary information can be collected through the installation of judiciously placed boring, wells, and/or geophysical investigations. A geophysical survey, "ground truthed" by drilling data (both existing and new), may be the most cost-effective means of filling data gaps. A conservative time estimate for completing this investigation would be 2 to 3 months.

It is also recommended that the aquifer's hydraulic characteristics be determined at the site of the extraction system. The best method for doing this is by conducting pumping tests at the locations of possible intercept systems.

Drilling of wells in the exact area of the intercept system would also provide physical samples from which grain size, porosity, and shear strength could be determined. The grain size and porosity of the formation would determine the

maximum particle size from the treatment plant effluent that could be accepted by the recharge wells without causing significant plugging of the aquifer. The shear strength would indicate the feasibility of constructing subsurface drains.

The total hydrogeologic system encompasses the alluvial material and the underlying Denver Formation. Obviously, any flow from or to Denver sand units that subcrop near the hydrogeologic system needs to be taken into account when evaluating the flow in the hydrogeologic system. Potential flow from or to the Denver Formation is still uncertain at this time.

Present knowledge of hydraulic conductivity and groundwater gradients in Basin A Neck indicate that only part of the contaminated groundwater beneath Basin A will move through the alluvial channel to the northwest. Water table maps also indicate that groundwater flows from Basin A Neck toward the north and northwest. A comprehensive mass balance needs to be performed to determine what volumes of water are moving through the various conduits and formations.

8.2 TREATMENT SYSTEM

The water quality data used for this assessment were collected from wells in the general area of the proposed extraction and recharge systems from 1978 to 1987. As noted in Section 4.3, several data values were considered to be anomalous or outliers and were eliminated from the evaluation. To ensure that the data used for the design of the IRA are adequately represented by the design water quality data presented in this report, water samples should be collected from as many alluvial wells upstream and in the immediate vicinity of the proposed extraction systems as possible and analyzed for organic and inorganic contaminants and general water quality parameters. These analyses would ensure that temporal and areal variations in the contaminant concentrations have not skewed the data significantly to prevent identification of all target contaminants.

Severe scaling and plugging problems could occur in the activated carbon adsorbers due to high concentrations of hardness-related compounds. To

prevent precipitation of these compounds, acid may be added in the influent to this process. In-plant testing would be required to verify the success of this option and to determine appropriate chemical feed rates.

REFERENCES CITED

Arisman, R.K., et al. 1980, May. Experience in Operation of an Ultraviolet-Ozone Pilot Plant for Destroying Polycholorinated Biphenyls in Industrial Waste Influent. Proceedings of the 35th Annual Purdue Industrial Waste Conference. West Lafayette, IN.

Bhattacharya, S.K. and G.F. Parkin. 1988, April. "Fate and effect of methylene chloride and formaldehyde in methane fermentation systems." Journal Water Pollution Control Federation, Volume 60, Number 4.

RIC 81325R16
Black & Veatch (Black & Veatch Consulting Engineers). 1980, July. Final Design Analysis Liquid Waste Disposal Facility North Boundary Expansion Rocky Mountain Arsenal, FY80, Project No. 34. Prepared for U.S. Army Engineer District, Omaha - Corps of Engineers, Omaha, NE.

Bouwer, E.J. and P.L. McCarty. 1984. "Modeling of Trace Organic Biotransformation in the Subsurface". Groundwater, 22:4-433.

RIC 81266R27
Broughton, J.D., W.O. Miller, and G.B. Mitchell, 1979, June. Geology and Groundwater Definition Basin A Area, Rocky Mountain Arsenal, Denver, Colorado. U.S. Army Engineer Waterways Experiment Station.

RIC 87082R02
CDM (Camp Dresser & McKee, Inc.). 1986, December. Performance of Remedial Response Activities at Uncontrolled Hazardous Waste Sites (REM II). U.S. EPA Contract No. 68-01-6939. Feasibility Study First Operable Unit Rocky Mountain Arsenal Off-Post RI/FS Site. EPA Work Assignment No. 99-8611. REM II Document No. 198-FS1-RT-DNFC-1.

Consent Decree, Modified. 1988, June. United States of America, Plaintiff vs. Shell Oil Company, Inc., Defendant. In the United States District court for the District of Colorado. Civil Action No. 83-2379.

Clark, J.W., W. Viessman, Jr., M.J. Hammer. 1971. Water Supply and Pollution Control. 2nd ed. International Textbook Co., Scranton, PA.

Conway, R.A. and R.D. Ross. 1980. Handbook of Industrial Waste Disposal. Van Nostrand Reinhold Co., New York, NY.

COE. 1987, December. Feasibility Analysis, Basin F Interim Well System, Rocky Mountain Arsenal. Omaha District, U.S. Army Corps of Engineers.

RIC 87198R01
COE, Sirrine Environmental Consultants. 1987b, June. Final Engineering Report. Literature Research and Review of Groundwater Quality and Treatment Systems for Basin F. Rocky Mountain Arsenal.

DP Associates, Inc. 1987, September. Section Plots and Well Summary.

Ebasco. 1988, January. Draft Final Report. Hydrazine Blending and Storage Facility Wastewater Treatment and Decommissioning Assessment. Contract No. DAAK11-84-D-0017.

Ebasco. 1987, September. Task 26 Interim Response Action Assessment, Draft Report, Version 2.1. Contract No. DAAK11-84-D-0017.

RIC 85128R03
ESE (Environmental Science and Engineering, Inc.). 1986. Water quantity/quality survey. Task 4, Draft final screening program report, v. I, II, and III, prepared for Program Manager's Office, Rocky Mountain Arsenal Contamination Cleanup.

ESE. 1987. ESE Water Levels, Fall 1985 - Spring 1987 (unpublished).

ESE. 1988. Personal communication. Telephone conversation between D. Zigich of R.L. Stollar & Associates and Larry Cerrillo of ESE, regarding mapping of saturated alluvium in the area of Basin A Neck.

ESE. 1988a, April. Feasibility Study Technical Plan, Version 3.2. Contract No. DAAK11-84-D-0016.

Evans, R. 1988, April. Personal Communication. Telephone conversation between R. Evans of Chief Equipment Corporation and E. Kaastrup of Ebasco Services regarding bagfilters.

Frankel, I. and E. Juergens. 1980, March. Removal of Fluorides from Industrial Wastewaters Using Activated Alumina. EPA-600/2-80-058. U.S. Environmental Protection Agency. Cincinnati, OH.

Harkins, B. 1987, September 18. Personal Communication. Telephone conversation between B. Harkins, Inc. and J. Ford of Ebasco Services regarding use of evaporators to treat wastewater.

HPD, Incorporated. Undated. Pamphlet regarding evaporation technologies.

RIC 87089R01
JMM (James M. Montgomery, Consulting Engineers, Inc.). 1986, April. South Adams County Water and Sanitation District. Treatability/Feasibility Study for District Water Quality Improvement.

Jhawar, M. and J.H. Sleigh. 1975, January. "Meeting EPA Standards with Reverse Osmosis". A reprint from Textile Industries.

RIC 81295R13
Khan, A.A. and D.W. Thompson. 1978, December. Laboratory Bench Scale Study on Ultraviolet/Ozone Oxidation of Organic Contaminants in Groundwater from Rocky Mountain Arsenal. U.S. Army Engineer Waterways Experiment Station. Vicksburg, Massachusetts.

RIC 81327R03
Kolmer, J. 1977, November 10. Memorandum for: Mr. D. Wynne, RMA IR Project Officer. Subject: Organic Treatment Capabilities of the Granular Adsorption Process and the UV/Ozone Process. DRCPM-DR-T.

Lewis, K. 1987. Personal Communication. Telephone conversation between K. Lewis of Wester Filter Company and D. Gabel of Ebasco Services, Inc., regarding activated alumina systems.

May, J.H., and W.O. Miller. 1980, July. Memorandum for Record; Containment Alternatives for Basin F, RMA. Waterways Experiment Station, Corps of Engineers.

May, J.H. 1982. Regional Groundwater Study of Rocky Mountain Arsenal; Report 1, Hydrogeological Definition. U.S. Army Engineer Waterways Experiment Station.

RIC 83299R01
May, J.H., J.D. Crabtree, R.H. Hunt, and W.L. Murphy. 1983, September. Hydrogeology of Basin A/South Plants Area, Rocky Mountain Arsenal, Denver, Colorado, Phase 1. Geotechnical Laboratory, U.S. Army Engineer Waterways Experiment Station.

Matsumura, F., et al. 1978. Pesticide Microbiology. Edited by I.R. Hill, et al., pp. 623-667.

McShea, L.J., et al. 1986, August 24-27. Chemical Oxidation of Aqueous Pentachlorophenol and Phenolics by UV-Ozonation. Presented at the AICHE 1986 Summer National Meeting, Boston, MA.

Nyer, E.K. 1985. Groundwater Treatment Technology. Van Nostrand Reinhold Company, New York.

O'Brian, R.P. and J.L. Fisher. 1983, May. "There is an Answer to Groundwater Contamination". Water/Engineering & Management.

Perry, R.H. and C.H. Chilton. 1973. Chemical Engineer's Handbook, 5th Edition. McGraw-Hill, Inc. New York.

RIC 88054R01
PMSO (Project Manager Staff Office). 1987a. Rocky Mountain Arsenal North Boundary Containment/Treatment System Operational Assessment Report FY85/FY86, Volume 1 Report.

PMSO. 1987b. Rocky Mountain Arsenal Northwest Boundary Containment/Treatment System Baseline Conditions, System Startup, and Operational Assessment, Report for FY25/86, Volume 1 Report.

Rezai, M. 1982, May 10. Denver Plant Groundwater Treatment Pilot Plant Study. Technical Report No. 82-2. Shell Development Company Technical Department, Denver Plant.

RIC 81336R13
Rubel, F. and D. Hager. 1978, September. Feasibility Study for the Removal of Excess Fluoride from Activated Carbon Effluent.

Rubel, F. and F.S. Williams. 1980, August. "Pilot Study of Fluoride and Arsenic from Potable Water," U.S. Environmental Protection Agency. EPA-600/2-80-100. Municipal Environmental Research Laboratory, Cincinnati, OH.

SAIC (Science Applications International Corp.). October, 1985. Remedial Action at Waste Disposal Sites: Handbook (Revised). Prepared for Environmental Protection Agency (PB87-201034).

Sienko, Mitchell J. and Robert A. Plane. 1974, Chemical Principles and Properties, 2nd ed. McGraw-Hill, Inc. New York, NY.

Spangler, M.G. and R.L. Handy. 1982. Soil Engineering, 4th Edition. Harper & Row, New York, N.Y.

RIC 84153R01
S-R (Stearns-Roger Engineering Corp.). 1983, November. Final Report South Plants Groundwater Treatment Pilot Plant. Rocky Mountain Arsenal. Denver, Colorado. Contract No. DAAK11-81-C-0041.

Tabak, H.H. et al. 1981, October. "Biodegradability Studies with Organic Priority Pollutant Compounds." Journal Water Pollution Control Federation, 53.

Thibodeaux, L.S. 1985. Air Stripping of Organics from Wastewater. Proc 2nd National Conference on Complete Water, Chemical Abstracts 85:93800d.

RIC 81295R14
Thompson, D.W. and R.G. Sweder, Jr. 1978, October. Preliminary Evaluation of Various Activated Carbons for Treatment of Contaminated Groundwater at Rocky Mountain Arsenal. Prepared for: Office, Project Manager for Chemical Demilitarization and Installation Restoration, Aberdeen Proving Ground, Maryland.

RIC 86078R01
USAEWES (U.S. Army Engineers USAE Waterways Experiment Station). 1985, December. North Boundary Containment/Treatment System Performance Report. Rocky Mountain Arsenal, Denver, Colorado.

USATHAMA (United States Army Toxic and Hazardous Materials Agency). 1972-1986. Groundwater quality data from Tentime Computer System.

USATHAMA. 1975-1987. RMA Groundwater Quality Database Aberdeen Proving Ground, Maryland.

USEPA (U.S. Environmental Protection Agency). 1983. Treatability Manual, Vol. III: Technologies for Control/Removal of Pollutants. EPA-600/2-82-001c. Office of Research and Development, Washington D.C.

USEPA. 1980a. Treatability Manual: Vol. I, Treatability Data. EPA-600/8-80-042a. Office of Research and Development, Washington D.C.

USEPA. 1980b. Carbon Adsorption isotherms for Toxic Organics. EPA-600/8-80-023.

USEPA. 1985a, June. EPA Region VIII. Procedure for Handling of Materials from Drilling, Trench Excavation, and Decontamination During CERCLA RI/FS Operations at the Rocky Mountain Arsenal. Clarifications added July 19, 1985.

USEPA. 1985b, October. Remedial Action at Waste Disposal Sites. EPA-625/6-85-006c. Office of Research and Development, Cincinnati, OH.

Viessman, W., Jr. and M.J. Hammer. 1985. Water Supply and Pollution Control, 4th edition. Harper & Row, New York, NY.

RIC 81266R70
Vispi, M.A. 1978, September. Report of Finding, Rocky Mountain Arsenal Pumping Test. U.S. Army Engineer Waterways Experiment Station.

RIC 81295R18
Walters, A.S. Undated. Isotherm Study for Twenty-five (25) Specific Organic Compounds. Calgon Corporation, Pittsburgh, Pennsylvania.

Weber, W.J., Jr. 1972. Physiochemical Processes for Water Quality Control. Wiley-Interscience, New York, NY.

Wilson, J.T., et al. 1981. "Transport and Fate of Selected Organic Pollutants in a Sandy Soil," Journal of Environmental Quality, Volume 10, pp. 501-506.

Wood, S. 1988, April. Personal Communication. Telephone conversation between S. Wood of Calgon Carbon Corporation and E. Kaastrup of Ebasco Services, Inc. regarding carbon adsorption equipment for water treatment.

Yuan, J.R., M.M., Ghosh, S.M., Hornung, and R.J. Schlicher. 1983, July. "Adsorption of Arsenic and Selenium on Activated Alumina". Environmental Engineering, 1983. National ASCE Specialty Conference Proceedings. New York, NY.

Zeff, J.D., et al. 1983, May. Chemistry and Application of Ozone and Ultraviolet Light for Water Reuse - Pilot Plant Demonstration. Proceedings of the 38th Purdue Industrial Waste Conference, West Lafayette, IN.

APPENDIX A

ALLUVIAL WATER QUALITY SUMMARY

Statistical[1] Summary of Alluvial Groundwater Quality Data from the Southeastern Set of Wells in Basin A Neck. Page 1 of 3.

Parameter	Abbreviation	Hits/Samples	Reporting Level(2, 3) (ug/l)	Range(2) (ug/l)	Mean(2) (ug/l)	Median(2) (ug/l)	Henry's Law Constant (atm-m3/mole)	Molecular Wt
Aldrin	ALDRN	2/40	0.30	0.30-20	10	-	2.4×10^{-5}	265
Alkalinity	ALK	9/9	-	$160,000-1.0 \times 10^{6}$	480,000	390,000	-	-
Arsenic	AS	0/2	0.50	-	-	-	-	75
Arsenic-total (4)	ASTOT	17/36	0.50	0.01-0.67	0.13	0.035	-	-
Barium	BA	0/1	10,000	-	-	-	-	137
Benzene	C6H6	4/10	1.0	1.0-21	9.3	7.5	6.0×10^{-3}	78
Benzothiazole (5)	BTA/BTZ	1/2	-	1.2	-	-	4.4×10^{-6}	135
Bicycloheptadiene	BCHPD	0/8	1.0	-	-	-	9.2×10^{-3}	92
Bromoform	CHBR3	0/1	1.0	-	-	-	NA	253
Cadmium	CD	0/3	0.20	-	-	-	-	112
Calcium	CA	18/18	-	$18,000-1.4 \times 10^{6}$	560,000	560,000	-	40
Carbon tetrachloride	CCL4	0/10	1.0	-	-	-	2.4×10^{-2}	154
Chlordane	CLDAN	0/2	1.5	-	-	-	9.6×10^{-5}	409
Chloride	CL	36/57	-	$68,000-7.6 \times 10^{6}$	2.4×10^{6}	1.9×10^{6}	-	35
Chlorobenzene	CLC6H5	2/9	1.0	1.0-4.0	2.5	-	2.6	113
Chloroform	CHCL3	8/9	1.0	2.0-1,300	170	4.0	2.9×10^{-3}	119
Chlorophenylmethyl sulfide	CPMS	5/38	10	2.5-12	12	15	1.9×10^{-3}	159
Chlorophenylmethyl sulfone	CPMSO2	13/46	10	19-1,100	330	230	1.2×10^{-7}	191
Chlorophenylmethyl sulfoxide	CPMSO	10/46	10	14-62	34	33	1.5×10^{-7}	175
Chromium	CR	0/3	5.9	-	-	-	-	52
Conductivity (6)	COND	9/9	-	1,200-14,000	11,000	13,000	-	-
Copper	CU	0/1	0.20	-	-	-	-	64
Dibromochloropropane	DBCP	10/54	0.40	0.61-3.4	1.2	0.84	3.1×10^{-4}	236
Dichlorobenzenes	CL2BZ	0/8	1.0	-	-	-	NA	147
Dichlorodiphenylethane	PPDDE	0/2	5.0	-	-	-	1.1×10^{-4}	318
Dichlorodiphenyl trichloroethane	PPDDT	0/2	5.0	-	-	-	9×10^{-5}	355

(1) Zero values not included in statistical summary.
(2) Reporting level, range, mean, median rounded to two significant figures when possible.
(3) Most common reporting limit. Some hits may be lower than detection limit indicated.
(4) Value of 110,000 excluded from statistical summary.
(5) Includes data for BTA and BTZ.
(6) Units are micromhos/centimeter.
NA Not available.
\- Not applicable.

Statistical(1) Summary of Alluvial Groundwater Quality Data from the Southeastern Set of Wells in Basin A Neck.

Parameter	Abbreviation	Hits/Samples	Reporting Level(2, 3) (ug/l)	Range(2) (ug/l)	Mean(2) (ug/l)	Median(2) (ug/l)	Henry's Law Constant (atm-m3/mole)	Molecular Wt
1,1-Dichloroethane	11DCLE	0/2	1.0	-	-	-	$6x10^{-4}$	99
1,2-Dichloroethane	12DCLE	0/2	0.59	-	-	-	$1.3x10^{-3}$	99
1,1-Dichloroethylene	11DCE	0/2	0.94	-	-	-	$3.4x10^{-2}$	97
1,2-Dichloroethylene	12DCE	0/2	1.0				$6.6x10^{-3}$	97
2,4-Dichlorophenoxyacetic acid	24D	0/1	10,000	-	-	-	NA	221
Dicyclopentadiene	DCPD	4/50	10	9.0-100	63	68	$1.9x10^{-2}$	132
Dieldrin	DLDRN	2/40	0.30	0.32-0.33	0.33	-	$1.4x10^{-5}$	381
Diisopropylmethyl phosphonate	DIMP	44/56	10	3.0-41	5,700	1,600	$4.7x10^{-5}$	193
Dimethyldisulfide	DMDS	0/2	1.1	-	-	-	$7.3x10^{-3}$	94
Dimethylmethyl phosphonate	DMMP	0/3	20	-	-	-	NA	124
Dithiane	DITH	29/42	5.0	5.5-7,000	1,500	460	NA	120
Endrin	ENDRN	0/40	0.30	-	-	-	$4.4x10^{-7}$	381
Ethylbenzene	ETC6H5	0/2	1.2	-	-	-	$6.4x10^{-3}$	106
Fluoride	F	17/56	100	1,000-6,000	1,800	1,300	-	42
Hardness ($CaCO_3$)	HARD	9/9	-	$1.0x10^6$-$4.8x10^6$	$2.8x10^6$	$3.8x10^6$	-	-
Hexachlorocyclopentadiene	CL6CP	0/2	1.4	-	-	-	0.014	273
Iron	FE	0/1	0.01	-	-	-	-	56
Isodrin	ISODR	4/47	0.50	1.1-24	11	10	$4.8x10^{-4}$	365
Lead	PB	0/3	20	-	-	-	-	207
Lindane	LIN	0/1	0.04	-	-	-	NA	291
Magnesium	MG	15/17	400	1,000-630,000	270,000	250,000	-	24
Manganese	MN	1/1	-	1,100	-	-	-	55
Mercury	HG	0/1	2.0	-	-	-	-	201
Mercury-total	HGTOT	0/11	2.0	-	-	-	-	-
Methoxychlor	MEXCLR	0/1	10,000	-	-	-	NA	346
Methylene chloride	CH2CL2	1/1	-	6.8	-	-	$2.6x10^{-3}$	85
Methylisobutyl ketone	MIBK	0/10	5	-	-	-	$1.1x10^{-4}$	100

(1) Zero values not included in statistical summary.
(2) Reporting level, range, mean, median rounded to two significant figures when possible.
(3) Most common reporting limit. Some hits may be lower than detection limit indicated.
NA Not available.
\- Not applicable.

Statistical(1) Summary of Alluvial Groundwater Quality Data from the Southeastern Set of Wells in Basin A Neck.

Parameter	Abbreviation	Hits/Samples	Reporting Level(2, 3) (ug/l)	Range(2) (ug/l)	Mean(2) (ug/l)	Median(2) (ug/l)	Henry's Law Constant (atm-m3/mole)	Molecular W
Nitrite/Nitrate	NIT	0/10	0.05	-	-	-	-	-
Oxathiane	OXAT	24/39	5.0	6.7-840	210	90	NA	104
pH (7)	PH	9/9	-	6.3-7.3	-	7.0	-	-
Potassium	K	11/11	-	2,900-30,000	19,000	24,000	-	39
Selenium	SE	0/1	1,000	-	-	-	-	79
Silvex	SILVEX	0/1	1,000	-	-	-	NA	270
Sodium	NA	47/47	-	120,000-$4.6x10^6$	$1.4x10^6$	$1.2x10^6$	-	23
Sulfate	SO4	11/11	-	160,000-$1.9x10^6$	$1.1x10^6$	$1.2x10^6$	-	96
Tetrachloroethylene	TCLEE	4/9	1.0	3.0-15	6.9	4.9	$2.6x10^{-2}$	166
Toluene	MEC6H5	0/10	1.0	-	-	-	$6.6x10^{-3}$	92
Total organic carbon	TOC	2/2	-	16,000-19,000	17,000	-	-	-
Toxaphene	TXPHEN	0/1	0.05	-	-	-	NA	410
1,1,1-Trichloroethane	111TCE	0/2	1.5	-	-	-	$1.4x10^{-2}$	133
1,1,2-Trichloroethane	112TCE	1/1	-	1.6	-	-	$9x10^{-4}$	133
Trichloroethylene	TRCLE	2/9	1.0	2.0-3.0	2.5	-	$9.1x10^{-3}$	132
m-Xylene	13DMB	0/2	1.4	-	-	-	$5.6x10^{-4}$	106
Xylenes (8)	XYLEN	0/10	0.10	-	-	-	$5.6x10^{-4}$	106
Zinc	ZN	1/1	-	51	-	-	-	65

(1) Zero values not included in statistical summary.
(2) Reporting level, range, mean, median rounded to two significant figures when possible.
(3) Most common reporting limit. Some hits may be lower than detection limit indicated.
(7) Standard pH units.
(8) Combined value for all xylenes.
NA Not available.
\- Not applicable.

Statistical(1) Summary of Alluvial Groundwater Quality Data from the Northwestern Set of Wells in Basin A Neck. Page 1 of 4.

Parameter	Abbreviation	Hits/Samples	Reporting Level(2, 3) (ug/l)	Range(2) (ug/l)	Mean(2) (ug/l)	Median(2) (ug/l)	Henry's Law Constant (atm-m3/mole)	Molecular Wt
Aldrin	ALDRN	2/60	0.30	0.15-8.3	4.2	4.2	2.4×10^{-5}	265
Alkalinity	ALK	24/24	-	51,000-260,000	180,000	170,000	-	-
Arsenic	AS	7/20	3.9	6.0-25	16	18	-	75
Arsenic-total	ASTOT	12/27	0.50	0.012-0.63	0.16	0.021	-	-
Atrazine	ATZ	0/3	6.0	-	-	-	1.2×10^{-9}	216
Barium	BA	0/1	10,000	-	-	-	-	137
Benzene	C6H6	6/26	1.3	2.4-4.0	3.1	3.0	6.0×10^{-3}	78
Benzothiazole (4)	BTA/BTZ	0/9	20	-	-	-	4.4×10^{-6}	135
Bicarbonate	HCO3	25/25	-	120,000-260,000	180,000	170,000	-	61
Bicycloheptadiene	BCHPD	0/5	1.0	-	-	-	9.2×10^{-3}	92
Bromoform	CHBR3	0/1	1.0	-	-	-	NA	253
Cadmium	CD	0/28	5.2	-	-	-	-	112
Calcium	CA	56/56	-	31,000-870,000	360,000	320,000	-	40
Carbon tetrachloride	CCL4	0/31	2.4	-	-	-	2.4×10^{-2}	154
Chlordane	CLDAN	0/5	1.5	-	-	-	9.6×10^{-5}	409
Chloride	CL	106/110	-	$23,000-2.8 \times 10^{6}$	840,000	570,000	-	35
Chlorobenzene	CLC6H5	6/27	0.58	2.0-6.9	5.0	5.6	2.6	113
Chloroform	CHCL3	4/29	1.4	2.0-29	10	4.5	2.9×10^{-3}	119
Chlorophenylmethyl sulfide	CPMS	6/49	10	2.6-150	47	23	1.9×10^{-3}	159
Chlorophenylmethyl sulfone	CPMSO2	23/57	10	6.9-7,400	1,000	320	1.2×10^{-7}	191
Chlorophenylmethyl sulfoxide	CPMSO	8/57	10	9.5-93	46	50	1.5×10^{-7}	175
Chromium	CR	5/23	6.0	7.3-190	63	55	-	52
Conductivity (5,6)	COND	46/46	-	920-10,000	5,100	2,400	-	-
Copper	CU	2/24	7.9	25-93	59	-	-	64
Dibromochloropropane	DBCP	20/125	0.20	0.19-22	2.1	0.92	3.1×10^{-4}	236
Dichlorobenzenes	CL2BZ	0/2	1.0	-	-	-	NA	147

(1) Zero values not included in statistical summary.
(2) Reporting level, range, mean, median rounded to two significant figures when possible.
(3) Most common reporting limit. Some hits may be lower than detection limit indicated.
(4) Includes data for BTA and BTZ.
(5) Units are micromhos/centimeter.
(6) Values less than 500 excluded, and value of 8,600,000 excluded from statistical summary.
NA Not available.
\- Not applicable.

Statistical[1] Summary of Alluvial Groundwater Quality Data from the Northwestern Set of Wells in Basin A Neck.

Parameter	Abbreviation	Hits/Samples	Reporting Level(2, 3) (ug/l)	Range(2) (ug/l)	Mean(2) (ug/l)	Median(2) (ug/l)	Henry's Law Constant (atm-m3/mole)	Molecular Wt
Dichlorodiphenylethane	PPDDE	0/28	0.053	-	-	-	1.1×10^{-4}	318
Dichlorodiphenyl trichloroethane	PPDDT	0/28	0.07	-	-	-	9×10^{-5}	355
1,1-Dichloroethane	11DCLE	1/28	1.2	1.4	-	-	6×10^{-4}	99
1,2-Dichloroethane	12DCLE	4/25	0.61	0.73-0.86	0.78	0.76	1.3×10^{-3}	99
1,1-Dichloroethylene	11DCE	0/26	1.1	-	-	-	3.4×10^{-2}	97
1,2-Dichloroethylene	12DCE	0/29	1.2	-	-	-	6.6×10^{-3}	97
2,4-Dichlorophenoxyacetic acid	24D	0/1	10,000	-	-	-	NA	221
Dicyclopentadiene	DCPD	15/99	10	10-580	90	53	1.9×10^{-2}	132
Dieldrin	DLDRN	9/59	0.30	0.072-1.4	0.51	0.37	1.4×10^{-5}	381
Diisopropylmethyl phosphonate	DIMP	61/112	10	2.6-3,600	960	930	4.7×10^{-5}	193
Dimethyldisulfide	DMDS	0/28	1.8	-	-	-	7.3×10^{-3}	94
Dimethylmethyl phosphonate	DMMP	1/29	15.2	313	-	-	NA	124
Dithiane	DITH	22/57	5.0	22-2,900	430	190	NA	120
Endrin	ENDRN	7/61	1.0	0.30-2.3	0.89	0.69	4.4×10^{-7}	381
Ethylbenzene	ETC6H5	0/28	1.3	-	-	-	6.4×10^{-3}	106
Fluoride	F	57/108	100	1,100-5,000	2,700	2,700	-	42
Hardness ($CaCO_3$)	HARD	60/60	-	$90{,}000-6.0 \times 10^{6}$	1.5×10^{6}	850,000	-	-
Hexachlorocyclopentadiene	CL6CP	1/24	0.70	0.29	-	-	0.014	273
Iron	FE	0/1	0.01	-	-	-	-	56
Isodrin	ISODR	5/59	0.50	0.15-4.4	1.2	0.53	4.8×10^{-4}	365
Lead	PB	0/28	19	-	-	-	-	207
Lindane	LIN	0/1	0.04	-	-	-	NA	291
Magnesium (7)	MG	54/57	400	10,000-610,000	190,000	80,000	-	24
Malathion	MLTHN	0/3	8.0	-	-	-	7.2×10^{8}	330
Manganese	MN	1/1	-	0.80	-	-	-	55

(1) Zero values not included in statistical summary.
(2) Reporting level, range, mean, median rounded to two significant figures when possible.
(3) Most common reporting limit. Some hits may be lower than detection limit indicated.
(7) Value of 6,300 excluded from statistical summary.
NA Not available.
\- Not applicable.

Statistical(1) Summary of Alluvial Groundwater Quality Data from the Northwestern Set of Wells in Basin A Neck.

Parameter	Abbreviation	Hits/Samples	Reporting Level(2, 3) (ug/l)	Range(2) (ug/l)	Mean(2) (ug/l)	Median(2) (ug/l)	Henry's Law Constant (atm-m3/mole)	Molecular Wt
Mercury	HG	1/20	0.24	0.25	-	-	-	201
Mercury-total	HGTOT	0/6	2.0	-	-	-	-	-
Methoxychlor	MEXCLR	0/1	10,000	-	-	-	NA	345
Methylene chloride	CH2CL2	0/27	5.0	-	-	-	2.6×10^{-3}	85
Methylisobutyl ketone	MIBK	0/27	13	-	-	-	1.1×10^{-4}	100
Nitrite/Nitrate (8)	NIT	25/43	0.40	150-13,000	3,300	2,100	-	-
Oxathiane	OXAT	22/48	5.0	8.0-290	59	31	NA	104
pH (9)	PH	62/62	-	6.3-8.7	-	7.5	-	-
Potassium	K	57/66	1,000	1,400-20,000	8,100	6,600	-	39
Selenium	SE	0/1	1,000	-	-	-	-	79
Silver	AG	0/2	1,000	-	-	-	-	108
Silvex	SILVEX	0/1	1,000	-	-	-	NA	270
Sodium	NA	95/97	30,000	$160,000-2.0 \times 10^{6}$	690,000	350,000	-	23
Sulfate	SO4	72/73	10,000	$78,000-6.8 \times 10^{6}$	1.4×10^{6}	840,000	-	96
Supona	SUPONA	0/3	7.0	-	-	-	3.8×10^{-9}	360
Tetrachloroethylene	TCLEE	8/26	1.3	1.9-22	13	13	2.6×10^{-2}	166
Toluene	MEC6H5	1/29	1.2	8.6	-	-	6.6×10^{-3}	92
Total organic carbon	TOC	2/2	-	4,500-9,800	7,200	-	-	-
Toxaphene	TXPHEN	0/1	0.05	-	-	-	NA	410
1,1,1-Trichloroethane	111TCE	0/29	1.7	-	-	-	1.4×10^{-2}	133
1,1,2-Trichloroethane	112TCE	0/29	1.0	-	-	-	9×10^{-4}	133
Trichloroethylene	TRCLE	5/18	1.1	4.0-8.9	6.7	6.8	9.1×10^{-3}	132
Unknown	UNK049 (10)	-	-	4.0	-	-	-	-
Unknown	UNK080	-	-	60.0	-	-	-	-
Unknown	UNK104	-	-	7.0	-	-	-	-

(1) Only data from alluvial wells was used. Zero values not included in statistical summary.
(2) Reporting level, range, mean, median rounded to two significant figures when possible.
(3) Most common reporting limit. Some hits may be lower than detection limit indicated.
(8) Values less than 1.0, and value of 380,000 excluded from statistical summary.
(9) Standard pH units.
(10) The numbers listed for unknowns correspond to their retention times.
NA Not available.
\- Not applicable.

Statistical(1) Summary of Alluvial Groundwater Quality Data from the Northwestern Set of Wells in Basin A Neck.

Parameter	Abbreviation	Hits/Samples	Reporting Level(2, 3) (ug/l)	Range(2) (ug/l)	Mean(2) (ug/l)	Median(2) (ug/l)	Henry's Law Constant (atm-m3/mole)	Molecular Wt
Unknown	UNK110 (10)	-	-	9.0	-	-	-	-
Unknown	UNK118	-	-	0.50	-	-	-	-
Unknown	UNK129	-	-	200	-	-	-	-
Vapora	DDVP	0/3	9.0	-	-	-	$2x10^{-7}$	221
m-Xylene	13DMB	0/28	1.4	-	-	-	$5.6x10^{-4}$	106
Xylenes (11)	XYLEN	0/30	2.5	-	-	-	$5.6x10^{-4}$	106
Zinc	ZN	9/15	110	22-370	110	74	-	65

(10) The numbers listed for unknowns correspond to their retention times.
(11) Combined value for all xylenes.
\- Not Applicable.

APPENDIX B

COMMENTS AND RESPONSES

ON ALTERNATIVES ASSESSMENT

STATE OF COLORADO

COLORADO DEPARTMENT OF HEALTH
4210 East 11th Avenue
Denver, Colorado 80220
Phone (303) 320-8333

Roy Romer
Governor

Thomas M. Vernon, M.D.
Executive Director

August 1, 1988

Mr. Donald Campbell
Office of the Program Manager
Rocky Mountain Arsenal Contamination Cleanup
Rocky Mountain Arsenal
North of Stapleton
Commerce City, CO 80022-2180

Re: State Comments on Draft Final Basin A Neck Groundwater Intercept and Treatment System Interim Response Action Alternatives Assessment, June, 1988.

Dear Mr. Campbell,

The State's specific concerns on this matter are enumerated in the enclosure. Nonetheless, the State is supportive of the concept of the Basin A neck intercept and treatment system and urges the Army to expedite its construction and operation. If you have any questions regarding the comments, please contact Mr. Jeff Edson.

Sincerely,

David C. Shelton

David C.Shelton
Director, Hazardous Materials and
Waste Management Division

cc: David Anderson, DOJ
Chris Hahn, Shell Oil Co.
Edward McGrath, Holme, Roberts & Owen
Connally Mears, EPA
Michael Gaydosh, EPA

RESPONSES TO COMMENTS OF
COLORADO DEPARTMENT OF HEALTH ON
DRAFT FINAL BASIN A NECK GROUNDWATER INTERCEPT
AND TREATMENT SYSTEM INTERIM RESPONSE ACTION
ALTERNATIVES ASSESSMENT

GENERAL COMMENTS

Comment 1: The Basin A neck area allows some of the most contaminated groundwater in Colorado to migrate and spread toward the boundaries of RMA. The contaminated Alluvial and Denver aquifers on RMA are contiguous with offsite drinking water aquifers. Consistent with USEPA policy and actions in Colorado, ARARs need to be identified for all interim actions. This determination is necessary in order to evaluate how well a[n] interim action can achieve ARARs, to the greatest extent practicable, considering the exigencies of the circumstances. The proposed treatment system will need to be capable of attaining, to the greatest extent practicable, identified ARARs and acceptable risk-based concentration levels. Therefore, the design of the intercept and treatment system must be based on an acceptable water quality performance criteri[on]. This major oversight in the report must be corrected.

Response: As stated in Section 3.0, ARARs are key criteria in the assessment of alternatives and must be met to the maximum extent practicable by the IRA. Proposed ARARs for this IRA have been sent to the Colorado Department of Health as a separate document. In accordance with the proposed Modified Consent Decree, the Decision Document for the Basin A Neck IRA will incorporate the Alternatives Assessment and the ARARs into a single document. Proposed chemical-specific ARARs have been incorporated into the text as Table 4.3-3.

Comment 2: The Denver formation sand units crop out adjacent to the Basin A neck. In this area, sand lenses and sand paleochannels are believed to be the major conduits for groundwater flow in the upper Denver. Furthermore, the Alluvial aquifer is known to recharge the upper Denver in this area. Therefore, the intercept and treatment system needs to be designed, constructed, and operated to minimize the further spread of contamination into the Denver formation.

Response: The goal of this IRA is to intercept and treat contaminated alluvial groundwater in the Basin A Neck area. Minimization of the further spread of contamination into the Denver Formation is consistent with this goal. As stated in Section 8.1, Denver sand units that subcrop near the hydrogeologic system need to be taken into account when evaluating the flow in the hydrogeologic system. However, the rate and direction of flow into or out of the Denver Formation is still uncertain at this time. Extensive

collection of additional data to define the hydraulic interconnections between the alluvium and the Denver Formation would be time consuming, costly, and beyond the scope of the IRA. The maximum benefits of any IRA are achieved with as early an implementation as possible. This IRA is not the Final Response Action for the contaminated groundwater in the Basin A Neck area. The Final Response Action will be designed to address all contamination pathways.

Comment 3: Further characterization of the Basin A neck hydrology and contaminant distribution is needed prior to the selection of the exact location for the system. Four important aspects of a more detailed siting study need to be considered and evaluated in this report. First, the location of the intercept system relative to subcropping Denver sand units may result in increased capture of flux recharge from the Denver units. Second, locating the system closer to the sources (i.e. South Plants area) could result in capturing more contaminants before they migrate into the underlying Denver formation. However, by locating the intercept system upgradient of the "neck" (towards Section 1), the desirable constriction occurring at the "neck" would be lost. Third, the faults and/or fault zones appear to affect the shallow aquifer flow and may affect the operation of the intercept and treatment system. Fourth, the northeast Denver sand conduit may have a significant affect on the flow and contaminant movement in the shallow aquifer. These aspects should be investigated and evaluated to assure the optimal site for the system.

Response: Further characterization of the Basin A Neck hydrogeology and contaminant distribution is needed prior to selection of the exact location for the system, as stated in Section 8.1. The four aspects presented in the comment were considered in evaluating possible locations for the intercept system as explained below:

(1) The alternatives assessment considered and proposed further characterization of subcropping and lateral Denver Formation units and their affect on the flow regime.

(2) The assessment examined two potential site locations without specific reference to source areas. Both sites are downgradient of several potential source areas. Source areas may include Basin A, South Plants, Section 36 "hot spots", and others. There is insufficient data to establish actual source areas. The potential advantages and disadvantages of the two sites have been discussed.

(3) Recent investigations by both the Army and Shell have indicated that there is no evidence of active faulting or of any adverse affects on the alluvial aquifer flow if any fault zones exist.

(4) The northeast Denver sand conduit does not appear to be a significant conduit for contaminants out of the Basin A area (Ebasco, 1987). Furthermore, the intent of this IRA is to address contaminated groundwater flowing through the alluvium in the Basin A Neck area. It is beyond the scope of this report to address all possible contaminant pathways from Basin A.

The Army agrees that all contamination sources and pathways should be addressed in the Final Response Action; however, the greatest benefit of an IRA is realized by early implementation. Delays would be counterproductive.

Comment 4: The findings from operations of the North Boundary Containment System, the Northwest Boundary Containment System and the Irondale System, including any problems encountered and the effectiveness of the systems, should be used to assess alternatives for the Basin A neck intercept and treatment system. A brief analysis of these systems, a discussion of their problems, and the effectiveness of these systems should be summarized and included in this report.

Response: Experience and findings from the other treatment systems have been included in this report. The reader is referred to Section 5.2 of this report as an example.

SPECIFIC COMMENTS

Comment 1: Pg. 3, para. 3 - The sentence "Contamination present in groundwater in the Basin A neck area does not constitute a present threat to the public health or environment," is premature. Gross contamination has been identified in the Alluvial aquifer and the Denver Formation in this area. That contamination continues to migrate to the northwest and eventually offsite. Neither the onpost or offpost Endangerment Assessments are complete. Therefore, the State cannot and does not agree with the Army's conclusion on this matter. This unjustified statement needs to be deleted from the report.

Response: Contaminated groundwater flowing through the Basin A Neck area "does not constitute a present threat to the public health or the environment," as the groundwater use restrictions at RMA prevent contact or ingestion of this water.

Comment 2: Pg. 4, Section 3.2 - The Basin A neck intercept and treatment system must be designed to effectively treat all contaminants, not merely Army identified "contaminants of interest".

Response: Because the Endangerment Assessment has not been completed, the definition of "contaminants" is imprecise. "Contaminants" as used in this report, refers to chemical species identified during the analysis of samples collected at RMA. "Target analytes" were selected based on their concentration and frequency of occurrence and were used to select processes and develop loading rates for the treatment system. Other contaminants not listed as target analytes will also be removed by the proposed IRA treatment system. Chemical-specific ARARs were not available at the time the draft final assessment was completed. The text of Section 4.3.2 has been modified and Table 4.3-3 added to include the proposed chemical-specific ARARs that are now available. The addition of chemical-specific ARARs in no way alters the alternatives assessment.

Comment 3: Pgs. 12, 13 and Appendix A - The evaluation of groundwater quality in the vicinity of Basin A neck may not be adequate to design the treatment system. The limited sampling/analy[s]es of some parameters may bias the treatment system design. For example, methylene chloride and 1,1,2-trichloroethane are only reported as being sampled/analyzed once and were confirmed hits. While other contaminants such as DIMP and DBCP were sampled/analyzed as many as 112 to 125 times. Therefore, the treatment system should be designed with a margin of safety so it will be able to handle unknown concentrations of unexpected organics.

Response: Agreed. As stated in Section 8.2 water quality samples will be collected and analyzed from as many wells as necessary to allow for good design of an appropriate treatment system. A margin of safety will be incorporated in the system design. This is standard in engineering practice.

Comment 4: Pg. 15, Section 4.3.2 - Forty-one of the 84 analytes identified in the narrow Basin A neck area were eliminated from further consideration. Thirty-nine of the 73 analytes identified in the wide Basin A neck area were eliminated from further consideration. If these analytes were detected at high concentrations or found in numerous wells, they may be important constituents of the contaminant plume and should be considered in assessing treatment alternatives.

Response: As stated in Section 4.3.1, analytes eliminated from further consideration were unknowns that were either found in relatively low concentrations or had no detected concentrations above their reporting levels. These analytes are included in the data summary in Appendix A.

Comment 5: Pgs. 15-18 - Selecting an influent value based on a mean concentration of a particular contaminant may result in an under-design of the groundwater system. For example, the projected influent value for DIMP in the wide Basin A neck area is determined to be 5100 ppb (based on mean concentration), however the maximum concentration observed in that area is 41000 ppb. Since the treatment system may not be able to "blend" contaminants to a mean concentration, the projected influent value should be adjusted higher.

Response: It is very unlikely that the maximum concentration reported for a single well would be representative of the actual conditions. Very high (or very low) data values are usually outliers that artificially increase the mean concentrations. The mean concentrations presented in this report exclude zero values (below reporting levels), thereby artificially increasing the mean and projected influent values. In actual operating conditions, influent concentrations are generally lower rather than higher than the calculated mean concentration.

Influent groundwater from multiple intercept wells to the treatment system would be equalized in a sump prior to treatment. Changes in flow or concentration would have minimal effect on the treatment process. Normally, the only significant adjustment to be made for the activated carbon adsorption system in case of higher (lower) concentrations is to change the regeneration frequency. If modifications and/or additions to the treatment system are determined necessary or advantageous, changes will be made after the system is operational.

Comment 6: Pg. 15, para. 4 - The proposed system needs to be designed to treat inorganic contaminants such that all maximum contaminant levels (MCLs) and State groundwater standards are attained prior to injection into the aquifer(s).

Response: It is premature to assume that MCLs and state groundwater standards that apply to drinking water quality are applicable to remediation of RMA groundwater in the Basin A Neck area. System effluent will be treated again at the boundary systems prior to recharge to off-post aquifers. However, if the need for inorganic treatment is identified, appropriate processes will be added later. Chemical-specific ARARs were not available at the time the draft final assessment was completed. These proposed ARARs are available now and have been included in the text as Table 4.3-3. These ARARs in no way change the assessment.

Comment 7: Pg. 42, Table 6.2-1 - Has the remote (Denver formation) component of the proposed narrow Basin A neck system been included in all cost estimates? This report should include separate cost estimates for the two components of the narrow Basin A neck system.

Response: The extent of lateral Denver Formation sand units has not been established. The location shown in Figures 4-1 and 4-4 is conceptual and is not intended to delineate the size of the system, only its approximate location. There is insufficient data at this time to develop costs for the remote Denver Formation component of the intercept system. The costs presented in Table 6.2-1 do not reflect the costs associated with the remote system. The text has been modified to clarify this point.

Comment 8: Pg. 48, Section 7.2 - Should it become necessary to add air stripping to the treatment system, emission controls would be required to meet chemical- and location-specific ARARs or risk based levels.

Response: As stated in Section 6.3.1, air stripping does not appear to be a viable treatment alternative based on current data. If, however, future data indicate air stripping is a viable alternative or a possible add-on to the proposed system, all ARARs will be attained to the maximum extent practicable.

FISH AND WILDLIFE SERVICE
FISH AND WILDLIFE ENHANCEMENT
COLORADO STATE OFFICE
529 25½ Road, Suite B-113
GRAND JUNCTION, COLORADO 81505
(303) 243-2778

[redacted]

IN REPLY REFER TO:

July 29, 1988

Mr. David Parks
Program Managers Office
Building 111
Rocky Mountain Arsenal
Commerce City, CO 80022

Dear Mr. Parks:

We have reviewed the Basin A "neck" Intercept/Treatment System Draft Alternative Assessment and the IRA Draft ARAR's document for same. We have no comments about the technological aspects of either defining the problem of groundwater contamination below Basin A or choosing a corrective or preventative solution to it. We do, however, hope that the timing of construction would be consistent with the necessary provisions for the protection of wintering bald eagles on RMA.

Construction in areas utilized by bald eagles has so far been restricted during the period November 1 to April 1. Bald eagles are known to use portions of the area mapped in Figure 4-1 of the Assessment document. Depending upon the final selection of the response alternative and the contaminated areas to be affected by construction, we recommend you contact either Mr. Pete Gober in Golden (236-2675) or Mr. Mike Lockhart of this office (303-243-2778) for specific guidance required to insure against unnecessary disturbance of wintering bald eagles.

Thank you for the opportunity to review the subject documents. You may also contact Mr. Rod DeWeese in Golden (236-2675) for clarification of the contents of this correspondence.

Sincerely,

Jeffrey D. Opdycke
State Supervisor

88-01643

RESPONSES TO COMMENTS OF
UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE ON
DRAFT FINAL BASIN A NECK GROUNDWATER INTERCEPT
AND TREATMENT SYSTEM INTERIM RESPONSE ACTION
ALTERNATIVES ASSESSMENT

The Fish and Wildlife Service made no comments requiring responses. However, the request that any construction be timed to be consistent with the protection of wintering bald eagles on RMA has been duly noted. Every effort will be made to prevent unnecessary disturbance of the eagles.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VIII
999 18th STREET - SUITE 500
DENVER, COLORADO 80202-2405

JUL 27 1988

Ref: 8HWM-SR

Mr. Donald L. Campbell,
Deputy Program Manager
Office of the Program Manager for
Rocky Mountain Arsenal
ATTN: AMXRM-TO
Commerce City, Colorado 80022-2180

Re: Rocky Mountain Arsenal, (RMA), Basin A Neck Groundwater Intercept and Treatment System, Draft Final Interim Response Action Alternatives Assessment, June, 1988.

Dear Mr. Campbell:

We have reviewed the above referenced report and have the enclosed comments. Please contact Mr. Connally Mears at (303) 293-1528, if there are questions on this matter.

Sincerely yours,

Robert Duprey, Director
Hazardous Waste Management Division

Enclosure

cc: Thomas P. Looby, CDH
David Shelton, CDH
Lt. Col. Scott P. Isaacson
Chris Hahn, Shell Oil Company
R. D. Lundahl, Shell Oil Company
Thomas Bick, Department of Justice
David Anderson, Department of Justice
Preston Chiaro, EBASCO

RESPONSES TO COMMENTS OF
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY ON
DRAFT FINAL BASIN A NECK GROUNDWATER INTERCEPT
AND TREATMENT SYSTEM INTERIM RESPONSE ACTION
ALTERNATIVES ASSESSMENT

GENERAL COMMENTS

Comment 1: In the text, it is stated that the wells chosen to be representative of the water quality data were selected "based on availability of data, screened interval, and date of sampling." Inclusion of these criteria relative to contaminant concentrations in the wells would be helpful in assessing the wide variation in the concentrations of some of the contaminants over the small distance between the wide Basin A Neck and the narrow Basin A Neck.

Response: As stated in Section 4.3-1, these data were retrieved from Morrison-Knudsen Engineers' groundwater quality database (USATHAMA, 1975-1987), the Army's database on the Tentime system (USATHAMA, 1972-1986), and data from Task 4 (ESE, 1987). Only data collected since 1978 were used to ensure that recent trends in groundwater contamination levels were not inordinately skewed by old data. Only wells screened in the alluvium were analyzed. Figure 4-4 identifies the wells utilized in this assessment. Summaries of these data for the two potential system locations are included in Appendix A. These data are available in the sources referenced above if such an analysis of vertical, areal, and temporal contaminant distribution would be helpful. Data excluded from the data summaries are delineated in Appendix A. However, as stated in Section 8.2, the design of the IRA should be based primarily on new water quality data to be collected during the early phases of development of the implementation plan for this IRA.

Comment 2: Page 3, Assessment Criteria, EPA requests omission of the sentence "Contamination present in groundwater in the Basin A Neck area does not constitute a present threat to the public health or the environment."

Response: Contamination present in groundwater in the Basin A Neck area does not constitute a present threat to the public health or the environment because the groundwater use restrictions at RMA prevent contact or ingestion of this water.

Comment 3: Page 5, what factors influenced the selection of the two sites as potential locations for the groundwater intercept system? A brief explanation would be helpful.

Response: In this report, two sites have been discussed as potential locations for the groundwater intercept system. Other locations are possible, but the two sites discussed are representative of different hydrogeologic regimes. The details of the outline presented below are available throughout the text. The following factors were taken into account based on available data:

- Hydrogeologic characteristics of the alluvium and the upper Denver Formation;
- Groundwater flow directions such as to maximize the capture of contaminants in the alluvium and possibly the upper Denver Formation sand units;
- Identification of areas of maximum possible saturated thickness and of more permeable alluvial units to ensure maximum contaminant capture;
- Location of maximum possible areas of contact of the alluvium with permeable Denver Formation sands that may or may not be contaminated;
- Presently known extent of contamination in the alluvium;
- Previously reported estimates of aquifer characteristics coefficients for the alluvial and upper Denver Formation sands;
- Potential areas to recharge treated water that will minimize the impact on the regional flow system;
- Potential contaminant source areas;
- Potential contributions to, and conflicts with, the Final Response Action; and
- The feasibility of various technologies in different hydrogeologic environments.

Comment 4: Page 12, it is stated that underlying gravel units in the narrow section of Basin A neck may serve as alternative flow paths. Is this to be evaluated in the characterization of the area?

Response: The presence of geologic units with high permeability and the potential for flow through these units will be evaluated as part of the preliminary design phase of this IRA.

Comment 5: Page 15, inorganic treatment should not be ruled out solely on the basis of procedures followed in other treatment systems on the RMA.

Response: If the treated groundwater wholly within RMA will be required to achieve standards of treatment for groundwater leaving RMA, the procedures followed in boundary systems on RMA are good guidance for the Basin A Neck area IRA. Proposed chemical-specific ARARs were not available at the time the draft assessment was completed. These ARARs are now available and have been included in the text as Table 4.3-3. These ARARs in no way change this assessment. Only two inorganic species were identified in the ARARs. Neither inorganic is currently a problem in the Basin A Neck area. However, the presence of inorganic compounds in the groundwater is relevant to this assessment as potential scalants in organic treatment processes. If inorganic treatment would produce benefits not identified in this assessment, such treatments may be added to the IRA after it is operational.

Comment 6: Page 20, it is stated that for the narrow Basin A neck, wells may not be a viable option for an area with such a potentially low hydraulic conductivity; yet, on page 42, they are listed among the "feasible" alternatives. The feasibility of this option should be reassessed after the aquifer properties are better defined.

Response: The characteristics of the Basin A Neck area hydrogeology are not well defined. Based on available data, wells in the narrow Basin A Neck may not be a viable option. However the available data are insufficient to eliminate this option from further consideration, and it is therefore listed among the potentially feasible alternatives. The preferred alternative for this IRA will be established following additional characterization of the hydrogeology in this area during the preliminary design phase of this IRA.

Comment 7: Page 21, it is stated that recharge wells in the narrow Basin A neck "would be difficult to keep operating efficiently and probably would not be feasible"; yet, on page 42, recharge wells are listed among the "feasible" alternatives. Perhaps, the feasibility of this method can be better assessed after revised characterization of the aquifer properties.

Response: Agreed; see response to Comment 6.

Comment 8: Page 40, in the use of leach pits as a recharge method would evaporative losses need to be replaced with purchased water and were these costs included in the costs summary, listed in Table 6.2-1, page 42?

Response: Evaporative losses may need to be replaced with purchased water, however, there are insufficient data to estimate the volume of water that may be lost by evaporation. Cost estimates for purchased water were not included in this report.

Comment 9: Page 40, In consideration of leach fields as a recharge method, use of the unlined basins, following their remediation, is mentioned. Is this being seriously considered and how will this use affect the method and degree of remediation of these basins, in particular, Basin C which was mentioned in the text?

Response: The statement in the text indicates that former unlined disposal basins, such as Basin C, would not be preferred sites for near-surface recharge. Former unlined disposal basins are not being considered as near-surface recharge sites but rather as locations to be avoided as near-surface recharge sites. The recharge site selected for this IRA should have no affect on the remediation of former disposal basins. To avoid confusion, the statement in the text has been modified to include both lined and unlined basins and to remove the reference to remediation. It is not the intent of this IRA to remediate or evaluate contaminated soils.

Comment 10: Page 46, in the selection of the preferred alternative as being the narrow Basin A neck system, were the costs of the remote system (mentioned on page 40) to prevent lateral flow in the Denver sands area considered?

Response: The extent of the lateral sands in the narrow Basin A Neck have not yet been determined. It is not possible to estimate the size or cost of an intercept system in this area without that information. The hydrogeologic investigation to be conducted as part of the preliminary design phase of this IRA will collect the data necessary to make size and cost estimates, and to verify that the narrow Basin A Neck location is the preferred site for this IRA.

Comment 11: Page 49, please give more specifics on the method to be used to evaluate the influence of the Denver sand units on the groundwater and contaminant flow.

Response: A comparison of the water levels in alluvial wells with the piezometric head of the lateral and subcropping Denver Formation sand units will indicate the potential for the alluvial aquifer to recharge, or be recharged by, the Denver Formation aquifers. An estimate of the cross-sectional area of Denver Formation sands can be developed from bore logs currently available as well as from any new bores or wells installed during the preliminary design phase of this IRA. Estimates of aquifer characteristics will be obtained from existing information and additional testing that will occur as needed during the design phase of this IRA. The water table gradient is well understood at this time, but can be confirmed by judicious water level measurements in existing wells. All these data can be used to estimate the flow from or to Denver Formation sands.

Comment 12: Page 50, in performance of the comprehensive mass balance, which contaminants will be assessed and what portion of the Basin A neck will be studied.

Response: The text does not state that the mass balance would be a "chemical" mass balance. A mass balance of "flow" through the various potential pathways would serve the purposes of this IRA. If a chemical mass balance is deemed necessary during the preliminary design work of this IRA, those analytes with the highest hit/sample ratio, generally inorganic species, would be used.

All potential pathways in the Basin A Neck area should be included in the study; specifically, the "Neck" itself, lateral and subcropping Denver sands, and any other alluvial or Denver Formation channels known to exist. A reasonable regional extent could be limited by the furthermost upstream well used in this report, approximately 3500-4000 ft upstream of the narrowest part of the Basin A Neck.

SPECIFIC COMMENTS

Comment 1: Page 12, Section 4.2, paragraph 3. The text states that ground water discharges from the underlying Denver sand units into the alluvium in the Basin A Neck and adjacent Basin A areas. Data to support this statement should be referenced.

Response: The text indicates that the groundwater flow may be discharging from the underlying Denver sand units. In addition, the text states that this is only one of the possible pathways. Data available from Task 4 (ESE, 1986) and in May (1983) indicate the potential exists for flow between the underlying Denver sand units and the alluvium. These documents are inconclusive as to the direction of flow and the likelihood of flow through adjacent, and often impermeable, stratigraphic layers.

Comment 2: Page 12, Section 4.3.1, paragraph 1. The projected influent water quality concentrations are mean values from data collected over a nine-year period (1978 to 1987). Temporal and spatial trends in the data should be evaluated to better predict what the likely influent concentrations will be, prior to designing the treatment system.

Response: The Army agrees. As stated in Section 8.2, to ensure that the data used for the design of the IRA are adequately represented by the design water quality data presented in this report, water samples will be collected from as many alluvial wells upstream and in the immediate vicinity of the proposed extraction system as necessary to allow for good design of an appropriate treatment system. The analytical results for these water samples will aid in predicting areal variations in the contaminant concentrations.

Comment 3: Page 19, Section 5.1.1, paragraph 2. A statement is made regarding the number of wells and well spacing that should provide sufficient drawdown to cause overlapping cones of depression. The calculation and data that were used to derive the stated number and spacing of wells, however preliminary, should be provided in an appendix or be referenced. Also, was the sloping water table surface considered when making the well capture zone estimates? Thirdly, the "available data" indicating that more wells may be required in the narrow Basin A Neck location compared to the wide Basin A Neck location should be included, via an appendix, additional discussion and/or a reference to the appropriate documents.

Response: A computer-modeled Theis analysis using the assumptions presented in Section 4.2, including the sloping water table, was used to derive the number of wells and well spacing for the wide Basin A Neck location. The analysis used in this alternatives assessment is similar to that presented in the Task 26 IRA Assessment

(Ebasco, 1987); however, the flow rate was modified from the 35-50 gpm used in Ebasco (1987) to 14 gpm. It is inappropriate to present lengthy calculations in an alternatives assessment. Calculations and other detailed analyses will be available for review as part of the Implementation Document for this IRA.

The "available data" indicating that more wells may be required in the narrow Basin A Neck refers to the data indicating lower permeabilities in that area.

Comment 4: Page 22, Section 5.1.2, paragraph 5. It is agreed that recharging treated water downgradient would avoid problems of recycled flow. However, if soils in the downgradient recharge location are contaminated, then there is a strong possibility that flushing these soils with relatively clean ground water would cause a release of contaminants back into the alluvial aquifer. The text should be modified to include a discussion of soil quality in the proposed recharge area, and of the effects of flushing contaminated soils with clean recharge water. This comment also applies to the unsaturated subsurface soils that may become saturated for the recharge wells and recharge drains alternatives.

Response: It is premature to discuss soil quality in proposed recharge areas, as specific sites for recharge have not been identified. However, as stated in Section 6.2.1, areas with known soil contamination, such as unlined disposal basins, "would not be preferred." To prevent potential problems, such as those mentioned in the comment, these areas will not be chosen as near-surface recharge sites.

Comment 5: Page 22, Section 5.1.2, paragraph 4. The disadvantages associated with placing recharge wells close to extraction wells (recycling of treated water, increase in system costs) also applies to placing recharge drains close to extraction drains. The text should mention this potential disadvantage.

Response: The text has been changed to reflect this comment.

Comment 6: Page 26, Section 5.2, paragraph 5. As stated in Sections 6.3.2 and 8.2, it is likely that acid may be added to the influent water to avoid scaling and plugging problems within the activated carbon adsorbers. How will a decrease in pH of the influent water affect the adsorption capacity, adsorption rates, and overall efficiency of an activated carbon treatment system?

Response: The text states that if water hardness is a problem, the potential for precipitation of several salts could be minimized by pH adjustment in the form of acid addition. Lowering of pH in a carbon adsorption system generally increases the adsorption capacity, rates, and efficiency of the system (Wood, 1988).

Comment 7: Page 41, Section 6.2.2. How accurate are the costs presented in Table 6.2-1? Why weren't costs associated with disposal of contaminated material generated during construction factored into the capital cost estimates? Addition of disposal costs would make the capital costs presented in Table 6.2-1 more realistic and would aid in evaluation of the alternatives.

Response: Costs presented in Table 6.2-1 are intended to be used comparatively but should be representative of the order of magnitude costs that can be expected in the respective site locations. Disposal costs have been excluded because the volume of contaminated material is unknown. For this cost analysis, soils were assumed to be replaced in the excavation site on a last-out, first-in basis in accordance with USEPA guidance (USEPA, 1985a).

Comment 8: Page 46, Section 7.1, paragraph 2. More detail needs to be provided to support the selection of remote leach fields or wells. The text in Section 5.1.2 and available cross-sections indicate that the low permeability materials present in the unsaturated zone may significantly reduce the effectiveness of recharge via leach fields.

Response: Based on cost estimates, recharge wells or leach fields would be preferred; however, more detail is required before the selection of any alternative can be made. The hydrogeology of the Basin A Neck area will be more fully characterized in the preliminary design phase of the IRA. The feasibility of the various alternatives will be reassessed once these new data are available and utilized in the final design of the system.

Comment 9: Appendix A. Why were selected values, as indicated in the footnotes, excluded from the statistical summaries?

Response: As stated in Section 8.2, several values were considered to be anomalous or outliers based on comparisons of data and were excluded from the statistical summaries. The values excluded are footnoted in the appropriate tables in the Appendix A. The reasoning for the exclusion of these data was missing from Section 4.3 but has been included in this version.

AUG RECD

Shell Oil Company

One Shell Plaza
P.O. Box 4320
Houston, Texas 77210

July 29, 1988

Office of the Program Manager
for Rocky Mountain Arsenal
ATTN: AMXRM-PMO: Mr. David Parks
Building E-4460
Aberdeen Proving Ground, Maryland 21010-5401

Dear Mr. Parks:

Enclosed herewith are Shell Oil's comments on the Basin A Neck Groundwater Intercept/Treatment System Draft Alternatives Assessment, June 30, 1988.

Sincerely,

R. D. Lundahl

R. D. Lundahl
Manager Technical
Denver Site Project

RDL:ajg

Enclosure

cc: (w/enclosure)
Office of the Program Manager for Rocky Mountain Arsenal
ATTN: AMXRM-PM: Mr. Donald L. Campbell
Building E-4460
Aberdeen Proving Ground, Maryland 21010-5401

Office of the Program Manager for Rocky Mountain Arsenal
ATTN: AMXRM-RP: Mr. Kevin T. Blose
Commerce City, Colorado 80022-2180

Office of the Program Manager for Rocky Mountain Arsenal
ATTN: AMXRM-TO: Mr. Brian L. Anderson
Commerce City, Colorado 80022-2180

copy of
99-A11.2011

RESPONSES TO COMMENTS OF
SHELL OIL COMPANY ON
DRAFT FINAL BASIN A NECK GROUNDWATER INTERCEPT
AND TREATMENT SYSTEM INTERIM RESPONSE ACTION
ALTERNATIVES ASSESSMENT

Comment 1: Page 3. 3.0 Assessment Criteria

Shell suggests that the following statement be incorporated in this assessment document, e.g., as the lead paragraph of Section 3.0, to clarify the alternative selection process for this IRA.

For this IRA, the proposed Consent Decree specifies at the technology level an interim response action for Basin A Neck, i.e., "the design and construction of an alluvial groundwater intercept and treatment system." Consequently, this Alternatives Assessment document does not screen and evaluate a range of technology alternatives. Instead, this assessment evaluates and screens process-level alternatives within this technology set to the extent that existing data allows. Although this has reduced the number of alternatives, selection of a preferred remedial alternative at the process level is dependent on acquisition of additional data essential for design and on design calculations. As with other IRA's this selection (at the process level) will be accomplished during final design and, as part of the IRA Implementation Document, will be subject to review and comment by the Organizations."

Response: The Army finds no reference in the proposed Modified Consent Decree to either "technology level" or "process level" for any IRA. The proposed Modified Consent Decree specifies that the Groundwater Intercept and Treatment System in the Basin A Neck area should consist of "design and construction of an alluvial groundwater intercept and treatment system in the Basin A Neck area on the Arsenal" (paragraph 9.1 (e)). In addition, the proposed Modified Consent Decree states "the goal of the assessment shall be to evaluate appropriate alternatives and to select the most cost-effective alternative for attaining the objective of the IRA" (paragraph 9.6). The proposed Modified Consent Decree does not define the level of detail at which the IRAs were intended to be assessed.

"Technology level" and "process level" are terms subject to varied interpretation unless defined. The "intercept and treatment system" specified for the Basin A Neck area IRA in the proposed Modified Consent Decree is, as defined in ESE (1988a), a "Remedial Action Alternative." The Basin A Neck area IRA alternatives assessment has an "alternative" defined as a starting point and, in general, goes two levels of detail further by evaluating "technology processes" as defined in ESE (1988a). Evaluating technology processes allows a reduction in the number of feasible alternatives. In order to clarify the

approach to the alternative assessment for this IRA, the paragraph Shell proposed has been modified and incorporated in the text as follows:

> This assessment evaluates and screens "technology processes" as defined by ESE (1988a) to the extent that existing data allow. Although this has reduced the number of alternatives, final selection of the preferred remedial technology processes is dependent on acquisition of additional data essential for design. The selected technology process will be subject to review and comment by the Organizations and State as part of the IRA Implementation Document.

Comment 2: Page 5, first full paragraph.

In the first sentence, the reference should be to the proposed Consent Decree as revised June, 1988.

If (ESE, 1988) contains the best current understanding of the configuration of the saturated alluvium downgradient of the narrow Basin A Neck in Section 35, Figures 4-1 and 4-4 should be based on this source rather than on (ESE, 1986).

Response: The citation in the first sentence and throughout the document has been changed to the proposed Modified Consent Decree and has been corrected in the References. The proposed Modified Consent Decree was filed in the U.S. District Court for the District of Colorado on June 7, 1988. The modifications in this document do not affect the alternatives assessment for this IRA.

As noted in the references, ESE, 1988 is based on a personal conversation. The data attained in this conversation have not been finalized or published. The configuration of the bedrock surface and overlying saturated alluvium has not been defined well enough to develop final maps for this area. The dashed lines on Figures 4-1 and 4-4 indicate the area of uncertainty. An investigation of the hydrogeology in the Basin A Neck area will be conducted as part of the preliminary design work for this IRA. This investigation will refine the data presented in this report prior to design.

Comment 3: Page 12, 4.3 Water Quality.

Throughout this section and including Tables 4.3-1 and -2, "analytes" are discussed in the context of chemical compounds. In fact some of the analytes are water quality parameters.

Response: The text has been changed to define "analytes" as target contaminants, nontarget compounds, and water quality parameters.

Comment 4: Page 15, first paragraph.

Frequency of detection and concentration levels are not appropriate criteria "to aid in establishing the suitability of various treatment technologies." For most treatment technologies, physical and chemical properties of the compounds are the decisive factors.

Response: As stated in Section 4.3.2, "For the purposes of this assessment, a number of analytes were selected to characterize the aquifer contamination to aid in establishing the suitability of various treatment technologies." Frequency of detection and concentration levels were used to establish target analytes characteristic of the alluvial groundwater. The physical and chemical properties of these analytes were then used to aid in establishing the suitability of various treatment technologies as is apparent throughout Section 5.2.

Comment 5: Page 19, second paragraph under Wells.

What is the extraction rate associated with 10 to 15 wells spaced at 150 to 200 ft centers? The wide spacing between wells suggests a very high rate of extraction to produce an effective cone of depression.

Response: A Theis analysis was used to estimate the number of wells and yields from wells for an extraction system at the proposed location. With a spacing of 150 feet between wells, 10 to 15 wells would be placed in the extraction line. The wells would be pumped in the range of 1 to 6 gpm over the life of the system. Wells closer to the center of the extraction line would be pumped at slightly higher rates than wells located at the periphery of the extraction line. A sustained pumping rate of 14 gpm for the entire system should be achieved. Pumping rates in the high end of the 1 to 6 gpm range would be used initially to establish cones of depression.

Comment 6: Page 20, third full paragraph.

Referring to the last sentence, if the drain creates a groundwater trough, water will flow into the drain from both sides, resulting in a significantly higher flow than the original flow rate through the channel.

Response: Any extraction system (e.g.,. drain, wells) that creates a groundwater trough will draw water from both the upgradient and downgradient sides of the system. The amount of water flowing into the system will be dependent on the drawdown the system creates. Although the amount of water extracted by the system will undoubtedly be greater than the flow rate through the channel, the amount of extra water can be minimized by

controlling the rate of extraction at which the system operates. Therefore, the flow to the system would not be "significantly higher" than the flow through the channel.

Comment 7: Page 26, Activated Carbon.

A discussion of the disposition of contaminants after adsorption on activated carbon should be included in this section, i.e., where do they end up?

Response: The carbon on which contaminants has been adsorbed is regenerated or replaced when the treatment effluent quality degrades to an unacceptable level, as stated in Section 5.2. Regeneration is most commonly carried out by the carbon vendor. If regeneration is not possible, carbon disposal would be in a hazardous landfill. A detailed discussion of side stream treatment processes is beyond the scope of this report, but will be addressed in the IRA Implementation Document. For the purposes of this assessment, the carbon is assumed to be regenerated by the carbon vendor.

Comment 8: Page 33, Evaporation.

Evaporation can isolate and concentrate contaminants but further treatment and/or disposal will usually be required. Therefore, it is more likely to be used as a pretreatment step.

The first bullet under advantages is only true if there is no recovery of contaminants, i.e., in the residue concentrate or recovered vapors.

The first bullet under disadvantages is in fact the treatment step.

Response: The evaporation process may be one of several processes in a treatment train. Evaporation treats influent contaminated water by creating a vapor stream of volatile organics and/or a liquid/solid stream of contaminant concentrate. These side streams may require additional treatment or may be otherwise disposed.

The text describing evaporation has been modified to include a discussion of the possibility of sidestreams and to clarify the use of evaporation for groundwater treatment. The bullets under advantages and disadvantages have been changed appropriately.

Comment 9: Page 39, 6.1 No Action Alternative.

For some IRA's the Consent Decree specifies that the IRA will consist of an assessment and, as necessary, the selection and implementation of a response action. In the case of Basin A

Neck, it specifies that this IRA "consists of design and construction of an alluvial groundwater intercept and treatment system in the Basin A Neck area on the Arsenal." However, this should not preclude assessment of a No Action Alternative since this alternative may provide a useful baseline for assessment of other alternatives.

Response: As stated in Section 6.1, the proposed Modified Consent Decree states that the IRAs have been determined to be both necessary and appropriate (paragraph 9.1). This statement precludes the option of No Action. In addition, the Basin A Neck area IRA does not include the "as necessary" statement included in some IRAs.

Comment 10: Page 40, third paragraph.

"Although preferred, a hydraulic barrier is not required, and recharge wells could be used downgradient where the alluvium is more permeable."

Whether or not a hydraulic barrier is required or preferred will only be established when detailed analyses of alternative intercept systems are performed in the Basin A Neck intercept design phase.

Response: The Army agrees. However, a hydraulic barrier is preferred because it would minimize the bypass of contaminants, potentially increase the system flow to a level less damaging to pumping systems than the flow through the alluvial channel alone could provide, initiate flushing of some contaminated aquifer materials in the Basin A Neck area, and minimize costs and problems associated with other barrier systems such as slurry walls. The advantages and disadvantages of hydraulic barriers must be considered along with other system components to establish the most efficient system.

Comment 11: Page 44, third paragraph.

Comment should be provided on the disposition of the residue concentrate which, in the case of Basin A Neck groundwater, would contain the non-volatile fraction and some semi-volatiles present in the groundwater.

Response: As in the response to Comment 8, the paragraph in the text has been altered to include the possible dispositions of sidestreams, such as any residue.

Comment 12: Page 45, fourth and fifth paragraphs.

It should be noted that selection of flow rates, carbon adsorption vessel sizing, activated carbon usage rates, etc.,

will occur during preparation of the final design and that the values discussed in these paragraphs are for purposes of developing preliminary cost estimates and for assessing feasibility.

In the first sentence of the fifth paragraph, 170 mg should be 170 ug/L.

Response: Both comments are appropriate and have been incorporated into the text.

Comment 13: Page 46, third paragraph.

This paragraph oversimplifies the design decision process. Factors in addition to feasibility and cost will affect the selection of location and type of extraction/recharge systems. For example, the ease or difficulty of achieving an acceptable level of groundwater recovery at a given location, with or without a barrier system and for the different methods of extraction and reinjection, will be a major focus in the design. Also, there will be design and cost inter-actions, e.g., trade-offs, between the hydrologic and treatment systems.

The third sentence should be deleted since cost is but one of many factors which will affect the selection of the preferred alternative.

Response: The options outlined in the referenced paragraph delineate major decision pathways for alternative assessment and are not intended to oversimplify the decision process. The feasibility of a given alternative includes its ability to achieve an acceptable level of groundwater recovery at a given location, with or without a barrier system, and the applicability of different methods of extraction and recharge. Design phase trade-offs are inevitable and will be addressed in the IRA Implementation Document.

The third sentence of this paragraph has been modified to indicate factors other than cost will affect the selection process.

Comment 14: Page 46, last paragraph.

"For the IRA, the cost of a physical barrier wall does not seem justified in either the narrow or wide Basin A Neck locations. A system without a barrier wall in the wide Basin A Neck would be more cost effective than a system in the narrow Basin A Neck with a barrier wall."

While these statements may be true, they are not supported by any adequate analyses in this assessment report. Therefore, the option of a physical barrier system should not be rejected. This paragraph should be deleted.

Response: The conclusions drawn in this paragraph are supported by the preliminary cost estimates (Table 6.2-1), the area hydrogeology description (Section 4.2), the technology alternative descriptions (Section 5.1), and the alternatives screening and evaluation (Section 6.2). However, if new data substantially alter the understanding of the hydrogeologic regime from what is currently understood, barrier walls may be justifiable. The IRA alternative assessments are intended to be based on available data.

Comment 15: Page 47, Table 6.3-1.

Shell believes that both capital and operating costs displayed in this table are significantly understated for a process unit of this general type and size. However, without more description of the unit being estimated, additional comment is not possible.

Response: The costs presented in Table 6.3-1 are based on the estimates provided by the vendors referenced at the bottom of that page. The type and size of the system used for costing are described in Section 6.3.2. These costs are comparative, do not include facility costs, and are not intended to be final design cost estimates.

Comment 16: Page 48, first paragraph.

"The use of a hydraulic barrier, while preferred to minimize by-pass of contaminated water, is not required."

It is both not necessary and not possible to make this judgment before detailed evaluations of alternative systems are made.

Response: See response to Comment 10.

Comment 17: Page 49, first paragraph.

In the third sentence, substitute suitably permeable zones for highly permeable zones.

Response: This comment is appropriate and has been incorporated into the text.